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ECONOMIC GEOGRAPHY—ITS IMPORTANCE TO AMERICA.*

BY
ALBERT S. CARLSON, M.A.,
Dartmouth College, Hanover, N. H.

June 1, 1826, Vol. 1, of the *Franklin Journal*, and *American Mechanics Magazine;* Devoted to the Useful Arts, internal improvements, and General Science was published under the patronage of the Franklin Institute of the State of Pennsylvania.

In an essay on the "Rise and Progress of The Franklin Institute," on page 130 of that issue, we find the objectives of the Institute stated: "It enlists with pleasure, among its supporters, all persons disposed to countenance, and foster our manufactures."

A century later "a small group of citizens, among them many distinguished members of The Franklin Institute, considered whether there was a need of coördinate planning and orderly development of the region contiguous to and including Philadelphia, Wilmington, Trenton and Camden." The point at issue was: "Should the region be allowed to continue to grow in a hit-or-miss fashion, or should it be planned comprehensively in advance?" [1]

* Presented at a meeting held Thursday, April 9, 1936.

[1] "Regional Planning Federation of the Tri-State Metropolitan Area of Philadelphia," Report formulated and compiled by sub-committees of the Technical Advisory Committee, Press of Wm. F. Fell Company, Philadelphia, 1932.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

Consideration of this problem resulted in the organization in the fall of 1924 of the Regional Planning Federation of the Tri-State Metropolitan Area of Philadelphia.

These two developments gain in importance when viewed as a smaller phase of 2 of 3 broad periods in our industrial history. The Franklin Institute was founded when a growing population and the resultant increase in demand caused people to focus their attention on ways of furthering production. The second phase of our economic history began about 1880 when many of our production problems had been solved and business men shifted their attention to marketing and distribution. As Malcolm Keir says: "Then came the World War, leaving excess productive capacity and unusual conditions as to prices, employment and wages. It became evident that the old order was crumbling and a new one was rising.

"This third stage is an age not of production dominantly, nor of distribution dominantly, but one in which attention must be given to production and distribution alike, in which the effort of the nation's business interests is to coördinate broadly the forces and instrumentalities of both production and distribution and thereby secure a steady and continuing progress." [2]

As the Regional Planning Federation was founded as a practical means of solving local problems inherent in this latter stage of economic history, there has been likewise, in educational institutions and government administration, a growing tendency to view this period as one in which problems are complex and successful solutions, if they are to lead to a better balanced economy, must consider problems as having multiple causes. This view has been no stronger among any of the fields of knowledge than in the field of Geography.

The distinctive function of Geography is to describe and explain the relations between man and his natural environment. It examines and interprets the adjustments which groups of people have made to the combinations of natural environmental conditions. It weighs the opportunities and handicaps for living in the unit regions of the world. Economic Geography is that branch of Geography, and neces-

[2] Keir, Malcom, "Manufacturing," A Volume of Industries of America, The Ronald Press Company, New York, 1928, Preface.

sarily a very large one, that studies the adjustments of the industrial activities of man in detail to the physical environment. It seeks to show the function of the physical environment in production. The Economic Geographer asks three questions: Where is it possible, from the point of view of the physical environment, to carry on specific economic activities? Where does man choose to carry on these activities? Why does he choose to carry on these activities in certain places? The answers lie in the inherent qualities of land and man, and in the economic, social and political institutions which have evolved from these two basic factors. Many disciplines contain answers to these questions and it may seem as if there was no core. This is not so. To Economic Geography belongs the specific task of explaining the natural and proper action of the physical environment in our economic society.

Admittedly, the Geographer is dealing with a dynamic complex world. He realizes that neither statistics nor theoretical knowledge can fully compensate for the lack of personal practical experience. Therefore he emphasizes the need for actual study in the field and contact with the leaders of industry. He appreciates that the research files of many commercial houses contain excellent treatises on his subject and knows that, as business leaders realize the value of this data to society at large and to specialists working in the field who are able to view developments with a broad perspective, they will be ever more willing to aid in developing the science of Geography.

Mr. Chairman, because of the permanent value and timeliness of the methods and facts of Economic Geography, because in aims and activities The Franklin Institute has been a recognized and distinguished leader in the furtherance of the scientific study of industry, and because I dare to hope that this discussion will lead to increased appreciation of the objects of Economic Geography and to further aid in its development from those who are the leaders in the economic life of this great nation of ours, I was happy to accept your invitation to speak in this Great Metropolis to this distinguished audience of The Franklin Institute on the subject—"Economic Geography—Its Importance to America."

To secure the full value out of social sciences we should be able to grasp the ideas of multiple causation and multiple effect. The first step in the correct appreciation of the social complex is to recognize the unique relation of man to the natural environment. Plants and animals adapt themselves to their environment in a passive manner and more as a result of natural selection than does man. Man alters his environment. His cultural attainment, composed of intangible elements such as knowledge and acquired skill and of tangible elements such as railroads and power houses largely determine how man will choose to utilize his resources at any particular time. In addition to man and his culture operating in a given physical environment there are the basic human wants and social objectives of the group, whether that group be rural or urban, local or national.

Since multiple forces are operative at the same time in a given region they must all enter into the explanation of the economic development of that region. Recognizing this, the Economic Geographer approaches his problems carefully, but nevertheless with the purpose of explaining the part that the natural environment plays in determining this economic pattern and with the idea that "the natural environment, while not the only factor, is one of the chief molding forces in man's economic life. It follows that the best type of economic life is the one best adjusted to the physical environment. This does not imply that it should not be well adjusted to the social and other conditions of the region. The natural environment, however, sets the stage. It furnishes the scenery. Climate, soil, topography and position are persistent and abiding. To them ultimately adjustments must be made, both in the kind of development and in the degree of development." [3] In other words, for the purpose of economic and social analysis, we may view the natural environment as relatively fixed. This is also true of man's biological nature but not of his wants, social objectives and the institutional and technical means at his disposal. In this sense Geography deals with relatively permanent factors, but we realize that the force

[3] Roarback, G. R., "Regional Economic Geography," *American Economic Review Supplement*, March, 1926, Volume XVL, pp. 121–124.

and relative importance of the geographic factors change as civilization changes.

The force and potency of the physical environment was stronger before the industrial revolution when man was living mostly in a local, self-sufficient vegetable economy. He differed from us in lack of power, machinery and trade. His adjustment was to the local conditions. When James Watt released the energy found stored in coal he set the stage for most societies to become increasingly productive. Energy from fuels and the resultant utility of metals permitted a great increase in the mobility of goods, people and ideas. People concentrated in cities and specialization replaced self-sufficiency. The profitableness of a system of farming was no longer dependent only on local conditions, but also on conditions in far-flung competing regions. The depths of the earth likewise became objects of utilization. The geographic base of world economy was broadened and deepened.

A vegetable economy is static in comparison to a fuel-metal-exchange economy. The dynamic nature of the latter consists of the increased mobility of goods and ideas as well as rapid technical changes requiring new adjustments between man and the natural environment. The potency of geographic factors is less direct, less obvious and more intricate and complex in a fuel-metal-exchange economy. However, though the function of resources in our system may be less direct and more difficult to evaluate, it is nevertheless there and it ranks with man and his techniques in explaining the economic pattern of mankind. As Erich Zimmermann says, in his book "World Resources and Industries," "The nature and height of a civilization depends, to a large extent, on the natural physical basis, but vice versa, the utility of various environmental aspects depends on the kind of civilization which has developed or is developing therein." [4]

Theoretically the economic system because of efficient productive methods is capable of giving men untold leisure and wealth. It fails to do this in many ways. The methods and facts of Economic Geography provide us with important tools and give us perspective that should increase the efficiency

[4] Zimmermann, E. W., "World Resources and Industries," Harper and Brothers, New York, 1933, p. 6.

of the whole system because they permit us to view it in its actual operation in the field and to note where the industrial structure is properly adjusted and where it is maladjusted to the natural environment.

The geographic method is scientific. It makes accurate observations and careful records of a specific group of facts in their significant regional setting and follows them with research for explanations "to gain, if possible, the power of prediction." The chief means of recording facts on an areal basis are maps and photographs supported by the written word. The map and the photograph, especially the aerial photograph, are the most accurate means for arranging and classifying measurable geographic data.[5]

As a nation we have failed to realize the advantages that accrue from carefully made maps. We are in the predicament of a man who builds a factory without using a blueprint. We develop regions without first recording the regional elements and noting their amount and distributional characteristics. Most of our studies of social problems show "where social stresses are occurring and where major efforts should be undertaken, but these wheres are *not* geographic, they do not apply to actual localities or areas, but are abstract points, levels or movements in a generalized social structure or process." [6] To gain the proper value from a map we need to understand that the map has as dignified a role in the arrangement of ideas as any statistical analysis. When the map is not regarded as naive but as a scientific method for explanatory description it will be of increasing use and value to business leaders and students of the social sciences. The science of cartography is young. Business leaders and educational institutions, by encouraging and aiding the construction of better maps, can feel that future national development is being reared on a base of measurable facts.

[5] Bowman, I., "Geography in Relation to the Social Sciences," C. Scribner's Sons, New York, 1934, Chapter 4. The specifically geographic method of recording and analyzing the distribution of phenomena over the surface of the earth in their association was first adequately stated by Friedrich Ratzel, and most lately has been vigourously set forth and aptly illustrated by Isaiah Bowman in "Geography in Relation to the Social Sciences."

[6] Report of the Science Advisory Board, Washington, D. C., September 20, 1934, p. 220.

The map depicts the distributional characteristics of the measurable items in a region in line with the best known scientific methods. However, this does not imply that unmeasurable items, historical data and trends, and the economic pattern of competing regions may be omitted. It does imply that the explanations and conclusions to be arranged are based on the most careful picture that can be constructed of the tangible items in the region. The Geographer must consider less tangible items it is true but, on the other hand, other social sciences cannot neglect this organization of areal facts in their studies any more than the Geographer can afford to neglect the unmeasurable forces of the regional complex.

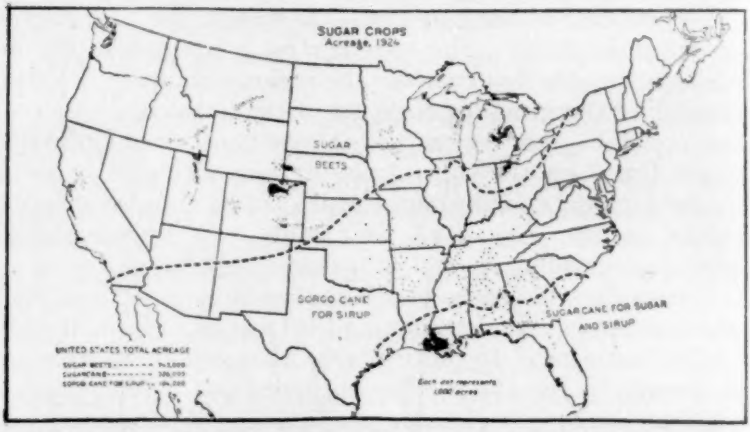
The making of the map record is merely the first step in a geographic study. The second step is to analyze the individual elements that compose the regional complex. This is followed by the grouping together of the individual elements that occur in the region. This synthesis or coördinated picture based on the sum of the various elements entering into the regional complex and the associated correlated explanations are the goal of all land study. As science this is regional geography; applied, it becomes regional planning.

Geographic conditions in general are more direct and their influences stronger in determining the location of farming than of manufacturing. In Agricultural Geography we attempt the answer to the three following questions. Where can a crop find the proper climatic conditions? Where does man choose to raise this crop? Why? In answering these questions we find the force of the geographic factors varying among different crops. This permits the division of all crops into two broad classes—those limited to small areas by their growth requirements, and those that may be grown over wide areas.

Sugar cane production in the United States is an example of a crop with limited natural requirements. Sugar cane is a tropical plant. Thus it is grown near its northern limit in the United States. This is permitted by tariff protection and by growing the plant as an annual instead of a perennial. Climate is the principal limiting factor in restricting sugar cane to certain well-defined areas. These areas are southeastern Texas, southern Florida and Louisiana, the latter being by far

the most important (Fig. 1). Sugar cane requires a uniformly high temperature, ample sunshine, and a large and constant supply of moisture. At any time up to harvest, cool, cloudy, or dry conditions will reduce the cane tonnage. The optimum annual rainfall for the crop in Louisiana is about 60 inches (Fig. 4). The more often heavy precipitation is followed almost immediately by bright sunshine rather than a succession of overcast, cool days with drizzling rain, the better will be the crop. Practically continuous sunshine is indispensable always, but irrigation water may be substituted

FIG. 1.



The two more important sugar crops are cane and beet. Sugar cane is not grown commercially outside of the almost frost-free lower Mississippi Delta of Louisiana and two small districts in Texas and Florida. (Source: "A Graphic Summary of American Agriculture," Miscellaneous Publication 105, U. S. Department of Agriculture.)

for rainfall in some localities. For ripening, sugar cane is benefited by dry, cool weather and a shortening of the days or periods of sunshine. In the sugar cane district of Louisiana the summer temperature averages 81° F. The frost-free season is over 250 days but growers allow the cane to stand until there is danger of frost to secure a high sugar content.

The plant grows in a variety of soils but they must possess definite characteristics for successful cane culture. The best soil and climatic conditions are found in the lower Mississippi Delta of Louisiana. The soils are well-drained Sharkey clay, and silt loam, silty clay loam and clay members of the Iberia

series, and the fine sand loams and silt loam of the Olivier series. These are all soils of high natural fertility retentive of moisture and with good sub-soil drainage developed under nearly flat surface features. Fair sub-soil drainage is necessary to prevent stagnant water and to insure soil aeration. Other factors of importance that are very favorable in Louisiana are the topography, labor supply, and the relative immunity from insects and diseases. The latter is probably due to the newness of the area. The operation of these factors has caused the growth in this section of the chief commercial sugar cane producing area of the United States.[7]

Since wheat, on the contrary, may be grown successfully over a wide area, economic, social and political factors play a relatively larger part in determining where an important wheat producing region shall occur in contrast to a crop with limited growth requirements. O. E. Baker states that wheat cannot be grown where the average temperature for the three summer months is below 57–58° F. There is no heat limit. Toward the poles the dry limit for the commercial production of wheat is as low as 9 or 10 inches of annual rainfall because of the small loss from evaporation and because it occurs when needed most. The wet limit is 40 inches of annual rainfall. In intermediate regions, like central and southern United States, it does not pay to raise wheat where the average annual rainfall is less than fifteen inches or more than fifty to fifty-two inches. In warmer climates the dry limit is twenty inches and the wet limit about seventy inches.[8] These conditions reduce the wheat growing area of the world to a rather small part of it, yet it is a very large one compared to other crops. This means that wheat can be grown in a large part of the United States as far as growth requirements are concerned, but economic and social conditions further limit the important producing areas.

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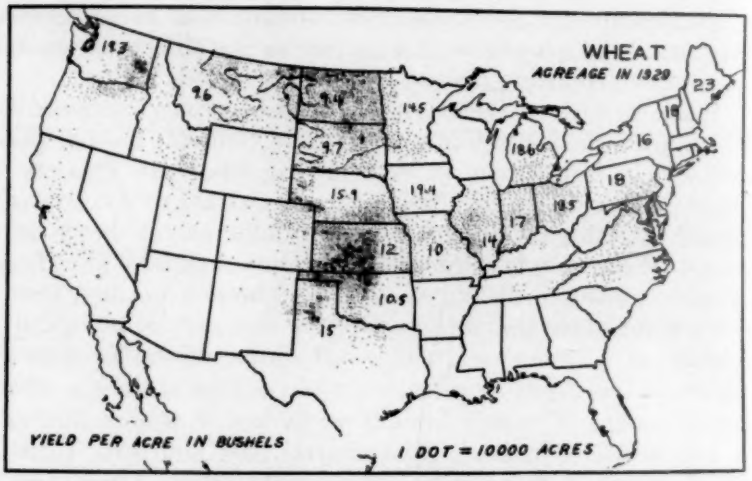
[7] Brandes, E. W., and others, "Sugar," *Yearbook of the U. S. Department of Agriculture*, Washington, D. C., 1923, pp. 151–228.

"The Cane Sugar Industry," Miscellaneous Series No. 53, U. S. Department of Commerce, Washington, D. C., 1923.

[8] Baker, O. E., "Geography and Wheat Production," *Economic Geography Magazine*, Clark University, Worcester, Massachusetts, Volume 1, No. 1, 1925, pp. 15–53.

Within the United States, the wheat yield varies from state to state. The maps show the striking fact that the major wheat producing areas are not where the geographic conditions approach the ideal for optimum yield (Fig. 2). A more detailed study of the Spring Wheat Region of the United States will help to explain this.[9]

FIG. 2.



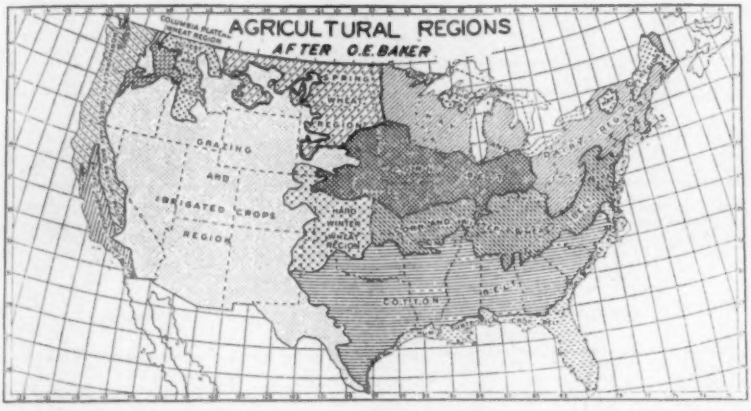
Although the states of the Great Plains are the chief commercial producers of wheat, the yield per acre, as shown by state averages, is higher in those states in which wheat is not the main crop. Economic and demographic factors, in addition to the geographic conditions, must be enlisted to explain this failure of yield and chief producing areas to coincide. (*Census of Agriculture*, U. S. Department of Commerce.)

The Spring Wheat Region is located in North and South Dakota and Montana (Fig. 3). Spring wheat is hard wheat. The invention in Budapest in the early seventies, and later introduction into the western wheat region of the United States, of the steel roller milling process (sometimes called "the gradual reduction process") increased the demand for hard wheat because it permitted the milling of the hard wheats so that the bran no longer broke up and gave the flour an off-color as had been true when the old-fashioned buhr stones were used. The shift of bread baking from the home to the

[9] Baker, O. E., "Agricultural Regions of North America—The Spring Wheat Region," *Economic Geography*, Volume 4, No. 4, 1928, pp. 399–343.

modern large-scale bakery allowed the application of scientific methods to bread baking. Under these conditions strong flours are most desired. These come from the hard wheats. Thus the increased demand for hard wheat with high gluten content resulted in a boom in these states in the last quarter of the 19th century. The demand plus the relative ease of building railroads in the region soon resulted in its being connected to the wheat markets.

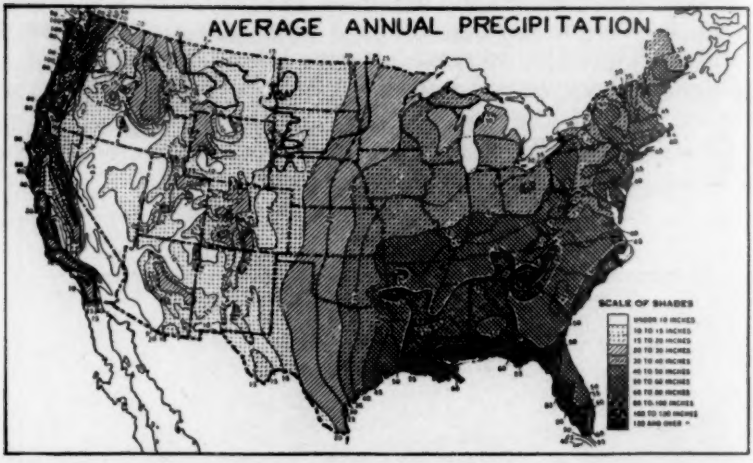
FIG. 3.



The country may be divided into agricultural regions based on the dominant crop in each region. (Source: U. S. Department of Agriculture.)

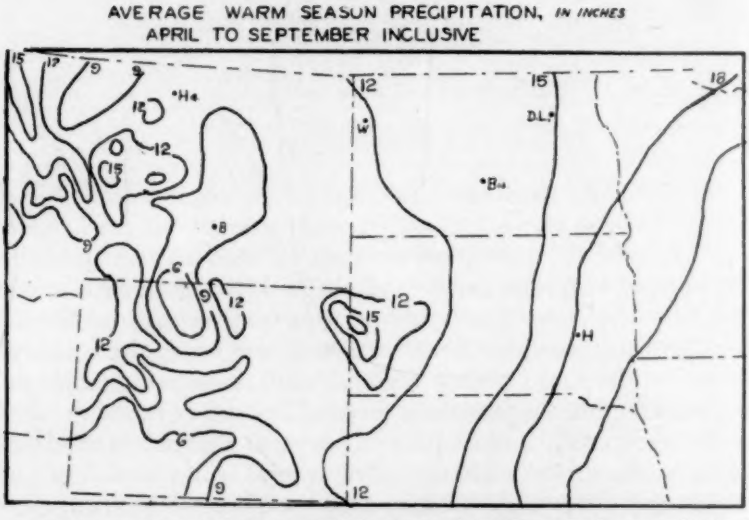
Climatically this region belongs to the continental type of climate that is characterized by wide annual ranges in temperature with a maximum rainfall in the warmer months. The low winter temperature and the lack of a deep snow cover prohibits the successful growing of winter wheat, while the short growing season eliminates corn except along the southern border. The low annual rainfall and summer maximum, 70–80 per cent. of it comes from April to September, and 40–50 per cent. during June, July and August, encourage spring sown crops such as spring wheat, oats and flax and discourage perennials (Figs. 4, 5). These conditions are average ones. But crops are not grown in average weather. They are grown in the weather of the moment and in this region it is variable—in annual total rainfall and in its occur-

FIG. 4.



The average annual precipitation in the Spring Wheat Region decreases from over 20 inches along the eastern border to just above 10 inches on the western one. (Source: U. S. Department of Agriculture.)

FIG. 5.

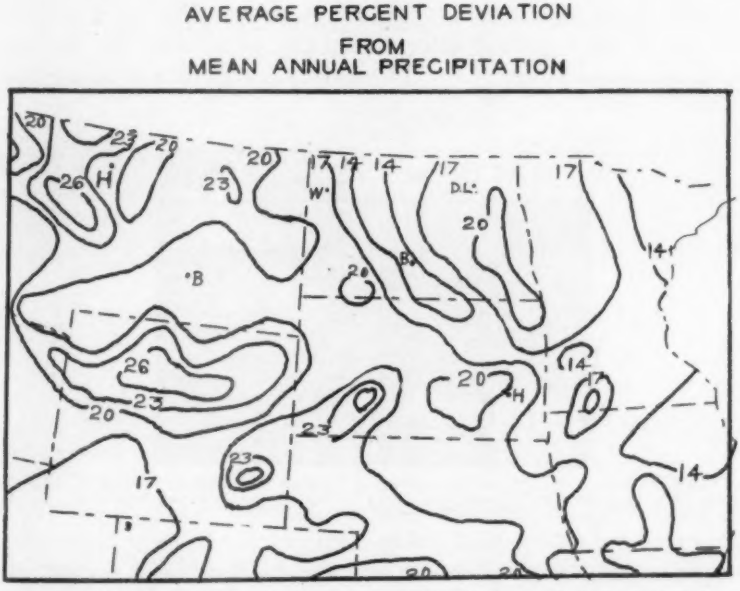


Over 70 per cent. of the annual precipitation in the Spring Wheat Region comes in the six warmer months. Ha-Havre, W-Williston, D.L.-Devils Lake, Bis.-Bismarck, Bi.-Billings. (Source: Atlas of American Agriculture, U. S. Department of Agriculture.)

rence during the year (Fig. 6). This means that to the risk of a short average growing season must be added variability of rain and frost each year. Thus poor crops and often complete failures must be expected. The system of farming must adjust itself to these conditions.

The level relief of the Spring Wheat Region plus the dry harvest season permits the most economical use of machinery in growing the crop. The fertile black to brown soils, high in

FIG. 6.



The farmer in the Spring Wheat Region must contend with the variability of annual precipitation as well as its meagre amount. (Source: *Atlas of American Agriculture*, U. S. Department of Agriculture.)

nitrates and lime, make for a high yield per acre when the extensive method of farming is taken into account while the climate and the soil together create a hard, gluten wheat.[10]

The cost of producing wheat in the region tends to be kept at a relatively low point because of the additional factors of

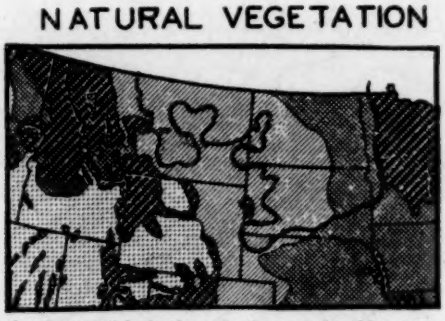
[10] See the classic treatment of the "Great Plains of the United States," by C. S. Marbut, J. B. Kincer, H. L. Shantz, and O. E. Baker, *The annals of the Association of American Geographers*, Volume 13, 1923.

low priced land in an area of few urban centers and sparse farm population due to the lack of forces that encourage these conditions.

This description of the general type of economic activity in a region and the separating out of the causal factors is an example of geographic analysis. The important part played by maps in this method is obvious. To end the discussion at this point might be satisfactory for some purposes, but it may be carried further with profit if we combine the separate causal factors in the sub-divisions of the general region.

The map of natural vegetation shows that the eastern section of the region is covered by tall grass and the western by short grass (Fig. 7).[11] The type of vegetation in an area

FIG. 7.



Tall grass vegetation (××××) is dominant in the more humid eastern section of the Spring Wheat Region and short grass vegetation (//////////) in the semi-arid western section, (Source: *Atlas of Natural Vegetation*, U. S. Department of Agriculture.)

is due largely to the climate and soil in that area. Also, the climate and the soils of the region may be divided into two general types. (Fig. 8).[12] In the eastern section we find a more humid, less variable climate and a fertile black soil of excellent texture and structure developed under a tall grass cover. In the western section we find a semi-arid more variable climate and a dark brown soil not as well-developed in texture and structure and lying under a cover of short

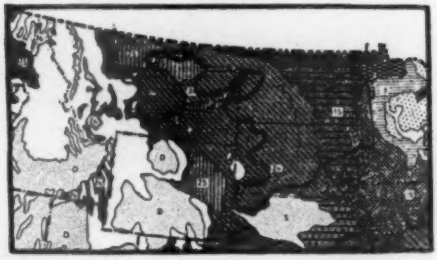
[11] Shantz, H. L., and Zon, R., "Natural Vegetation Section," *Atlas of American Agriculture*, U. S. Department of Agriculture, Washington, D. C., 1923.

[12] Marbut, C. F., "Soils of the United States," *Atlas of American Agriculture*, U. S. Department of Agriculture, Washington, D. C., 1935.

grass. The eastern section has a more diversified agricultural development than the western. Although wheat is dominant, oats and barley are also extensively grown and a great deal of hay is cut, while dairy cows are more important than beef cattle (Figs. 9, 10). Wheat is the dominant crop in the western section and the other crops are not as important.[13] This difference in economic development is due primarily to the geographic conditions in the two regions although nearness to market and older development of the former area is partially responsible. These differences may be classified and synthesized into types of farming areas

FIG. 8.

SOIL REGIONS



The soils of the Spring Wheat Region are very fertile. *Key* (15) Black soils, highly calcareous subsoils, (24) Chestnut-brown soils, calcareous subsoils, (25) Medium dark yellowish brown soils, calcareous subsoils. (Bureau of Soils, U. S. Department of Agriculture.)

(Fig. 11).[14] The current results of these differences in geographic conditions in the eastern and western sections of the Spring Wheat Region is testified to by a recent report of the National Resources Board delimiting areas that should be taken out of cultivation. A large part of the western section is so classified.[15]

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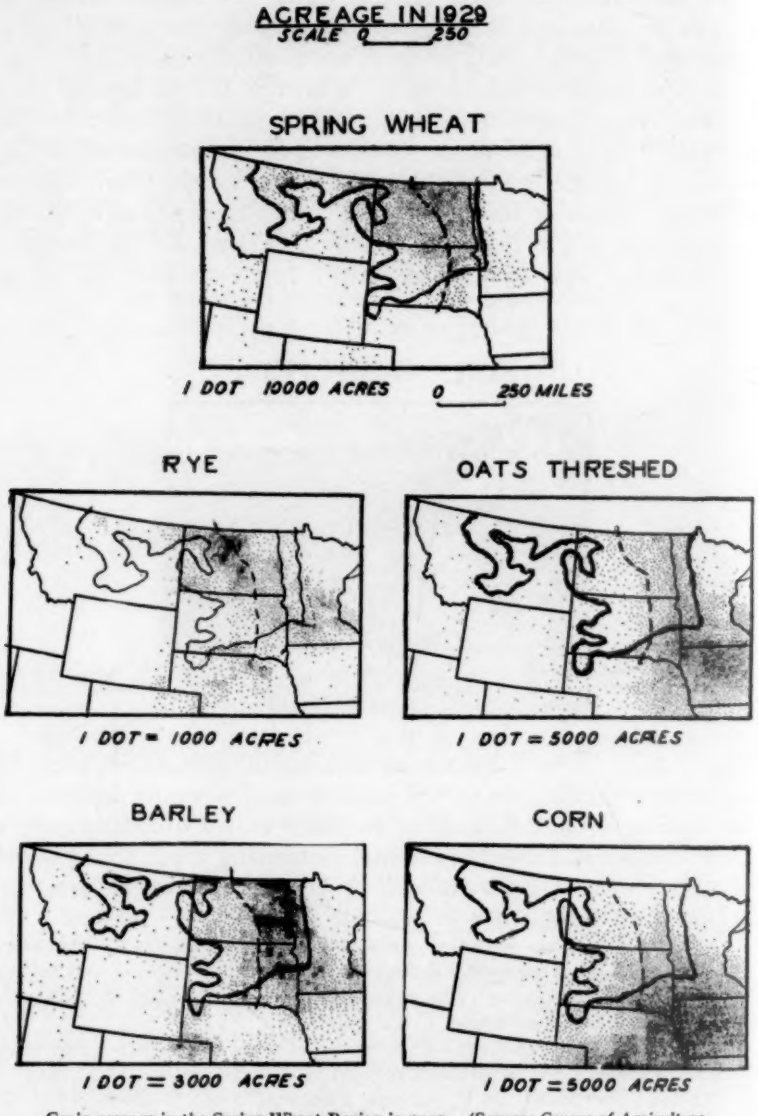
[13] Baker, O. E., Compiler, "A Graphic Summary of American Agriculture Based Largely on the Census," Miscellaneous Publication No. 105, U. S. Department of Agriculture, Washington, D. C., 1931.

[14] "Types of Farming in the United States," *Census of Agriculture*, Fifteenth, Bureau of Census, U. S. Department of Commerce, Washington, D. C., 1933.

[15] Report December 1, 1934, National Resources Board, Washington, D. C., Map entitled, "Areas in which it appears desirable to encourage permanent retirement of a substantial part of the arable farming and develop constructive use of the land not to be in farms," p. 16.

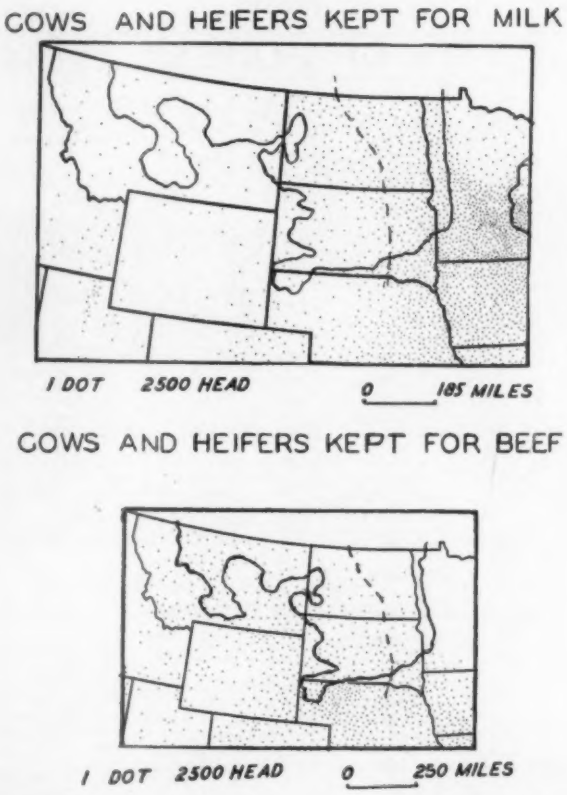
FIG. 9.



Grain acreage in the Spring Wheat Region in 1929. (Source: *Census of Agriculture*, U. S. Department of Agriculture.)

Although agriculture provides many fine examples of the part that the physical environment plays in fashioning the economic life of a region, it seems more appropriate this evening to center the remainder of our discussion about the function of natural resources in our industrial life.

FIG. 10.

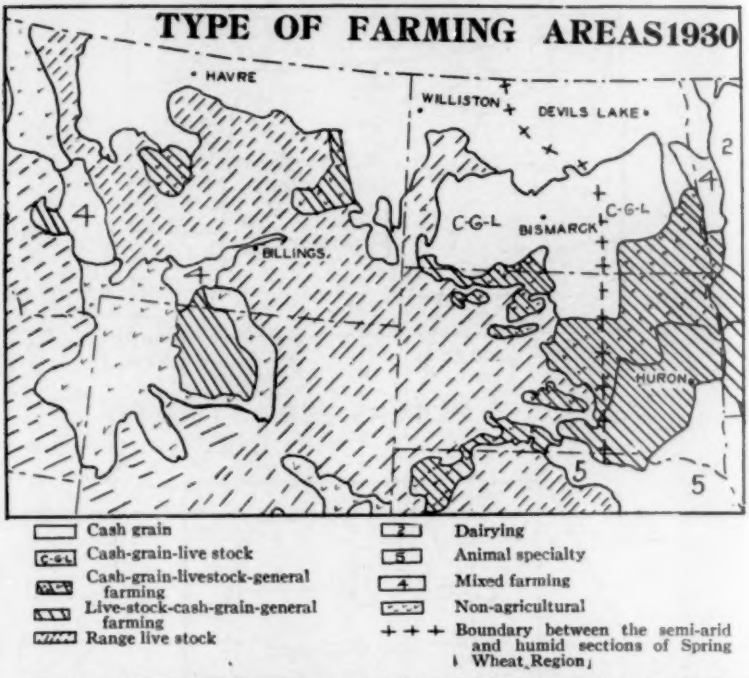


Cows and heifers kept for milk are relatively more important in the eastern section of the Spring Wheat Region and cows and heifers kept for beef in the western section. (*Census of Agriculture*, U. S. Department of Commerce.)

While surveying world industrial trends recently the noted French Economist, André Siegfrid, was led to state that Europe and her entire form of civilization was in jeopardy. He feels that we are witnessing the birth of a new era, the

beginning of which lies in the replacement of the tool by the modern factory that has been transformed into a mechanism that is standardized, automatic and interchangeable. Numbered parts and a few specialists permit the factory to be put together anywhere. Operation of the plant is so simple that it can be done by people with very little skill. To the mo-

FIG. 11.



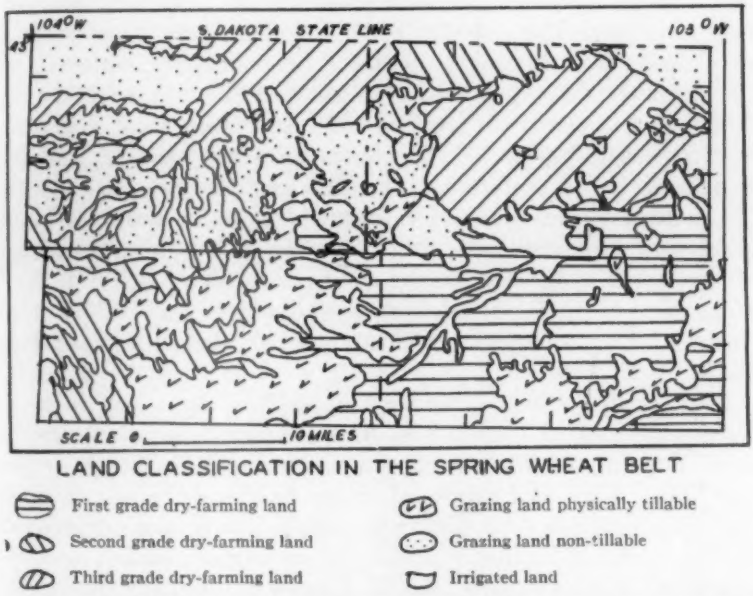
Farming in the drier western section of the Spring Wheat Region consists primarily of cash grain (wheat) and livestock. In addition to the cash grain type of farming in the wetter eastern section there is, in the southern half of it, more diversified farming. (Source: "Types of Farming in the United States," *Census of Agriculture*, U. S. Department of Commerce.)

bility of capital we must add the mobility of machines and the standardized factory. The manner in which different nations and continents are reacting to these new conditions is the fundamental problem of the period. The concrete expression of this development is seen in the increased industrialization of the British Dominions and in the loss of trade suffered by Lancashire due to competition from Japan.

Siegfrid suggests the consequences inherent in this development when he says, "a complete upheaval in the geographic distribution of world leadership is at stake." [16]

What part will the resources of the physical environment play in reshaping the industrial map of the world? Naturally, we are not going to attempt a complete answer to this question. However, an examination of some of the forces that

FIG. 12.



Land classification in a small area in Northwestern Nebraska in a part of the Spring Wheat Region. Land use maps of this type are necessary before intelligent appraisal can be made of our resources. (Land classification by the U. S. Geological Survey.)

are potent in accounting for the present distribution of manufacturing will help us to gain a clearer picture of the problems involved.

Industries may be divided into types on the basis of the sole or chief factors determining their location. The chief factors are raw materials, fuel, power, markets, labor and

[16] Siegfried, André, "The Clash of Continents," *Current History*, New York Times Company, April, 1935.

climate. Since nature seldom produces sharp boundaries or pure cultures we must expect an overlapping of these factors. Nevertheless, we can classify industries on this basis. For present purposes we may think of industry as divided into two broad groups, the raw material oriented type and the labor-market oriented type. The steel and cotton textile industries are appropriate examples.

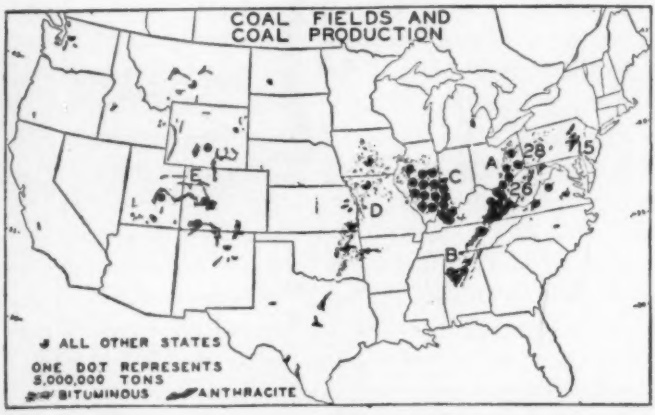
Iron and steel provide the structural basis of our industrial civilization. Steel cannot be mentioned without coal. Fuel and metal resources are interdependent. One cannot develop without the other. Both are inseparably associated with modern technology and have been decisive elements in the growth of capitalism. Modern industry, directly or indirectly, depends on iron or steel and coal, some for their raw material, but all for transportation, for energy, and for machinery. To understand the factors governing the location of the heavy iron and steel industry is to understand the basic principles which underlie the formation of the industrial map of the world. A few remarks concerning the location of steel industries in the United States and some general facts of world-wide application will aid us in evaluating the statement made by Siegfrid.

In primitive times, during the Middle Ages and later in Colonial America, when iron making technique was simple, small deposits of fairly high grade ore, local limestone or sea shells for flux, and charcoal from nearby forests provided the materials for iron making. These being ubiquitous the development of an iron industry in an area depended most on available markets even though they were limited to regions near the raw materials because of transportation costs. As demand increased local supplies of raw materials became insufficient. New inventions permitted the use of coal. Continued transportation difficulties and the limited area of the country open to settlement resulted in industrial development near the anthracite coal fields. The small scattered furnaces gradually disappeared.

When the early pioneers pushed through the Appalachian Barrier and into the Ohio Valley they widened the market and supply area for the iron industry and decreased its dependence on eastern ore and anthracite coal. Settlements in the Ohio

River Basin created a local market for plows, nails and tools. Topographic conditions encouraged the early location of fabricated iron plants at Pittsburgh based on markets accessible by river, and pig iron shipped in from Connellsville and the Juniata River district. The advantage of experience and an early start were intensified when methods for the use of bituminous coal were developed and local ore was used. Later the most economical production of pig iron called for the use of the coke made in the so-called Beehive oven. Profitable operation required coal of high carbon content.

FIG. 13.

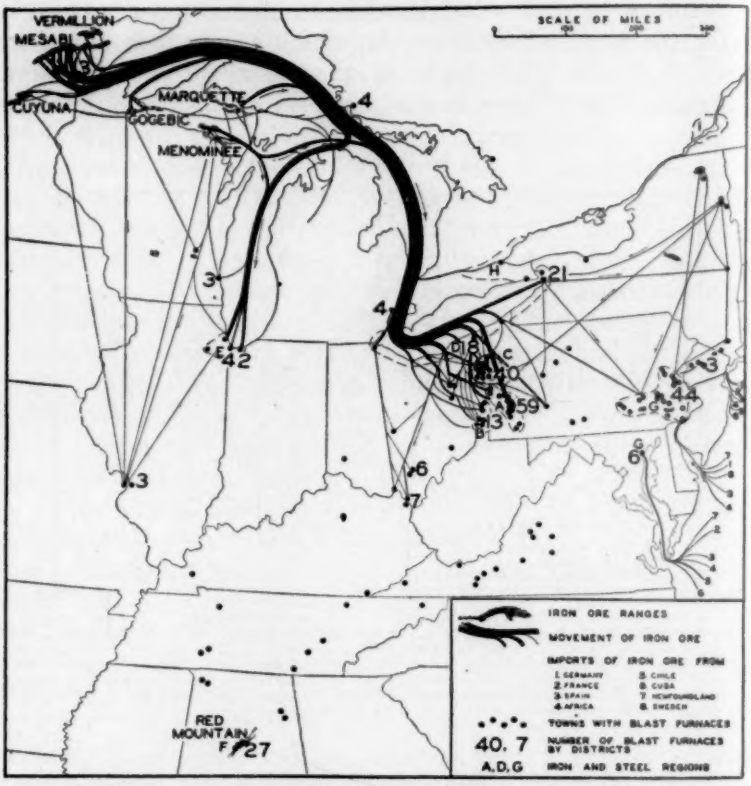


The coal fields: A, Northern Appalachian; B, Southern Appalachian; C, Eastern interior; D, Western interior; E, Rocky mountain. In a recent year the United States produced 520,000,000 short tons of bituminous coal and 75,000,000 tons of anthracite. The number "28" in western Pennsylvania stands for twenty-eight dots. The Appalachian coal fields produce nearly three-fourths of our bituminous coals. Note the lack of coal in the tier of states north of Pennsylvania and Indiana. Some of the southern states, the Great Plains, and the states of the far west lack large deposits of bituminous coal, but they have extensive fields of lignite or brown coal. (Courtesy C. F. Jones.)

Characteristics of coke prevented its transportation over great distances. Connellsville coal was the only suitable coking coal available (Fig. 13). At the same time Pittsburgh plants had easy access to Lake Superior ore (Fig. 14). The rapidly expanding West continued to provide markets. Thus, geographic conditions played a prominent part in the historical development of industrial Pittsburgh and then technological inventions tied the industry to Connellsville coal.

Since 1900 two factors have complicated the picture. The introduction of the by-product coke oven permitted the more economical use of coal containing less carbon and more volatile matter. This meant that steel plants could locate

FIG. 14.



Iron mining regions, the movement of ore, and blast furnaces in East Central North America. Iron and steel regions: A, Pittsburgh; B, upper Ohio Valley; C, Mahoning-Shenango Valleys; D; Lake Erie; E, Chicago-Gary; F, Alabama; G, Middle Atlantic; H, Ontario, Canada; I, Montreal. The width of the line is in proportion to the ore movement.

near various sources of coal and further from the Connellsville area. The power of coal to locate the industry was lessened up to the point where transportation costs or increased economies of coke manufacturing in By-product ovens permitted profitable operation. Local markets which

developed at a distance from Pittsburgh, plus the higher freight charge on finished metal products, and cheap Lake transportation encouraged new steel centers to develop in the Lower Lake Section. It is important to note that this was a movement toward markets and raw materials, but not far from coal (Figs. 13, 14).

Increasingly larger blast furnaces became necessary in later years and new types of demand required the use of more scientific methods of manufacture. The economies of heat called for the By-product ovens to be adjacent to the blast furnaces, while the economies of heat achieved by running the molten iron directly to the steel mill without cooling and re-heating tied the furnaces and rolling mills together. These technical improvements necessitated the production of coke, iron and steel in related plants. Separate organizations were at a disadvantage. Further, the new processes of ore reduction made possible the use of lower grade ore and of scrap iron and steel while the increased size of the blast furnaces and the combining of the various processes at one point required large amounts of capital. The new processes of ore reduction also caused a shift in emphasis from small deposits of high grade ore to large deposits of low grade ore. The advantages to be gained from integration resulted in the combining of the companies that were producing coke, pig iron and steel separately into large corporations with integrated plants located together. The increased scale of operations required assurance that large supplies of raw materials would be continually available. Thus, technical forces and the requirements of large amounts of capital combined to encourage the large steel corporations of today.

The effects of these developments are summarized by C. K. Leith as follows: "Four conditions must be met before a modern steel industry can be developed: (1) A huge ore reserve of a suitable grade in a limited area; (2) Accessibility to a large coal supply of proper grade for use in smelting; (3) Accessibility to population, large enough and with sufficient industrial development to furnish demand; (4) Control by people with organizing ability, driving power, technical skill, and capital to convert the ore into a form adapted to

demand." [17] The truth of these statements is easily recognized when we note the dominance of the United States, Germany and England in steel production (Fig. 15).

We have discussed the direct effects of coal and iron ore on steel plant location. What part does the market play? The development of the Lower Lake Centers is an example of movement to market and towards ore. However, it does not mean a very large increase in coal costs. Such development as that of the Bethlehem Corporation at Sparrows Point, Maryland, might also be construed as a movement from raw materials to market. It represents rather a movement toward cheap ore based on water transportation from foreign lands, cheap scrap metal and markets accessible by water, without a distinct increase in fuel costs.

FIG. 15.

Percentage by countries of world production of iron ore, Pig SW., Sweden; G. B., Great Britain; B & L., Belgium and Luxemburg; R, Russia; G, Germany; and S., Spain. East Central North America and West Central Europe smelt 95 per cent. of the world's iron ore, pour nearly 90 per cent. of the pig iron, and make 92 per cent. of the steel. (Courtesy C. F. Jones.)

We must look further for the answer to the question, "What part does the market play?" It lies in two directions. The one, which we won't attempt to answer directly, is hidden in the warp and woof of our whole complex economy. The other is explained by an examination of the immediate destination of the products of the steel industry, namely, automobile, railroad and machine manufactures (Fig. 16). These industries require large amounts of power. Therefore, they too have tended to locate at the coal fields and they profit because of nearness to fuel and to their raw materials as supplied to them by the steel industry. This tendency of

[17] Leith, C. K., "The World Iron and Steel Situation in its Bearing on the French Occupation of the Ruhr," *Foreign Affairs*, June, 1923. See also, Jones, C. F., "Economic Geography," Henry Holt and Company, New York, 1935, pp. 342–356.

the basic and secondary metal and machine industries to locate at the coal fields has caused a large population to concentrate in those areas. Thus the market for the steel industry tends to be at or near the coal fields of the world. The location of the steel industry can therefore be explained only in the terms of its constituent elements—coal, iron and markets bound together by transportation facilities at or near fuel supplies. However, in an analysis of this type we must guard against interpreting the inertia of invested capital

FIG. 16.

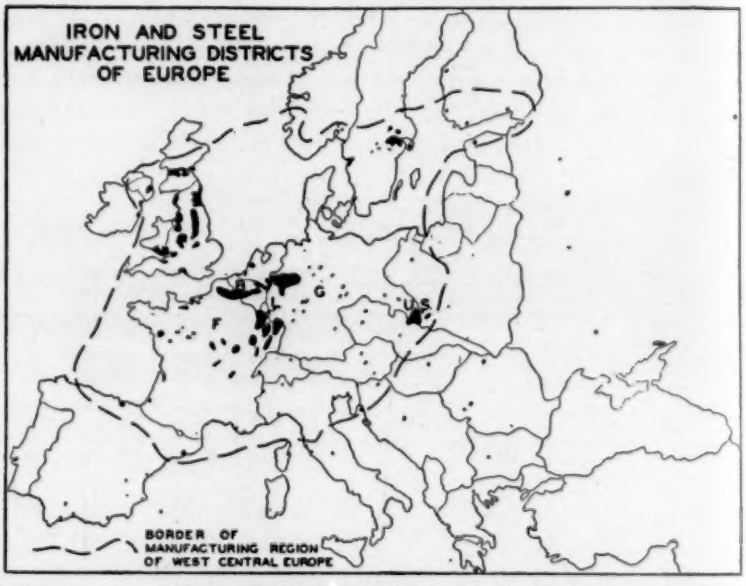
STEEL INDUSTRY LOCATED IN MORE THAN 250 COMMUNITIES FROM COAST TO COAST.

Map of the United States showing the location of the 433 plants which manufacture steel products covered by the Steel Code. (Courtesy American Iron and Steel Institute.)

as a reason for the location of an industry. It is an important factor at times, but it is not as permanent or basic as the other forces. Such artificial, temporary practices as basing point systems must be thought of in the same manner. The spending of $40,000,000 to $60,000,000 for the building of new plants in the Pittsburgh District at present seems to indicate that factors other than the "inertia of fixed capital" are operative in continuing Pittsburgh's dominant place among our manufacturing centers.

The interdependent nature of coal and iron and the technological and economic conditions that make it necessary for present steel plants to be highly integrated, with the resultant need of large raw material reserves, indicate that there is only one other region that can be thought of as comparable to the United States—namely, Northwestern Europe (Figs. 17, 18). There the raw materials are available and markets

FIG. 17.

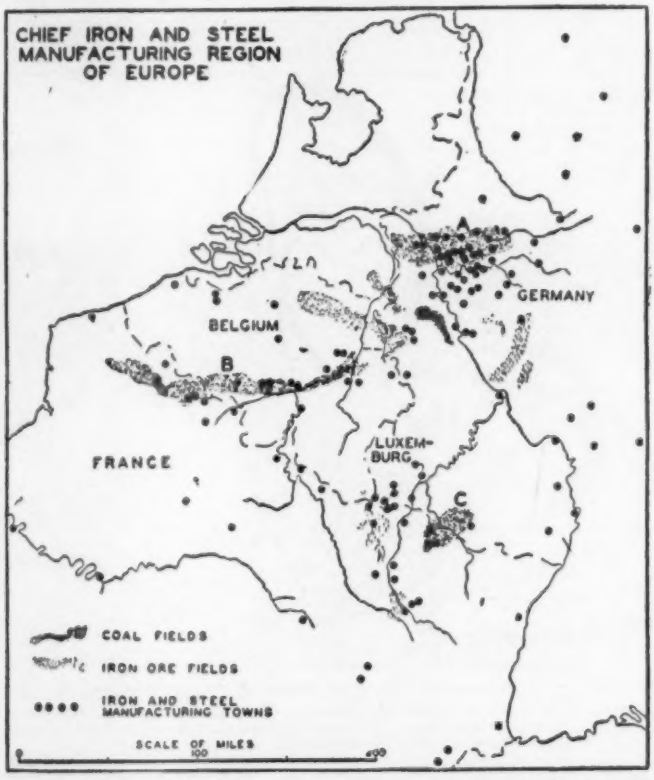


Nearly every country in Europe produces iron and steel, but two districts manufacture most of the Continent's pig iron and steel. (Courtesy C. F. Jones.)

and economic organization developed on a par with our own, although differences in nationality and political ambitions prevent the homogeneous and widespread markets that we possess in the United States (Figs. 18, 19). Speaking of Eastern Asia, C. K. Leith concludes that "it is not likely that the Far East will ever be able to build up an iron and steel industry comparable to that of Europe or North America. Japan has the organization and plant capacity, but it lacks the raw materials. If all of the supplies of the Far East could be pooled, a big industry could be developed, but even

that industry would be handicapped by low grade of ore and by the wide geographic separation. As it is, political boundaries interfere also" [18] (Fig. 20). The Union of Socialist Soviet Republics seems to be attaining a position just ahead of the Far East. Predictions are dangerous but may be useful

FIG. 18.



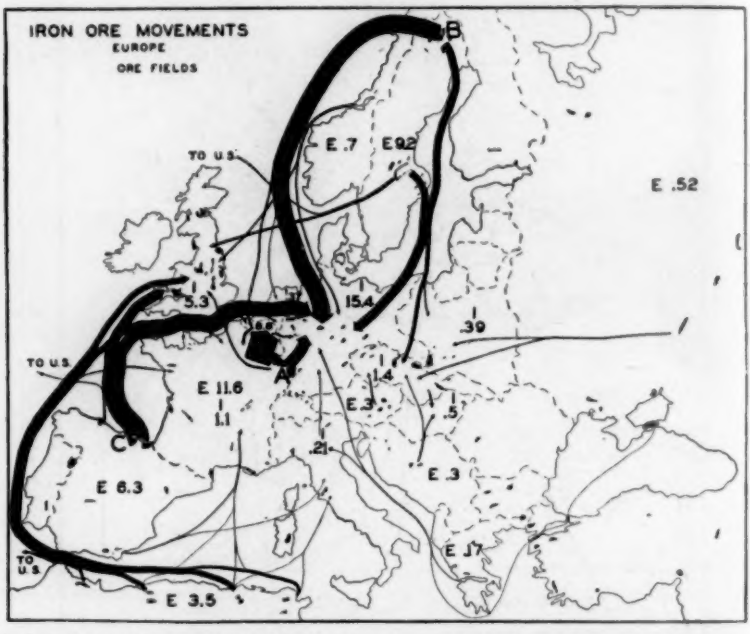
The three principal districts of this region are the Ruhr, central Belgium and Northern France, and northeastern France (Lorraine and Alsace) and Luxemburg. (Courtesy C. F. Jones.)

when used with caution. Knowledge regarding the amount and distribution of the world's ore and coal resources is necessary to an understanding of the industry's growth and geographical concentration.

[18] Leith, C. K., "The Mineral Resources of the Far East," *Foreign Affairs*, April, 1926, pp. 433–442.

Two further current developments need to be considered at this point. The development of the electric furnace may seem to indicate that there will be less dependence on coal in the future. There may be some truth in this idea, but it should be realized that at present only special, high-value steels can be profitably made in the electric furnace and it must be remembered that the large-scale development of the

FIG. 19.



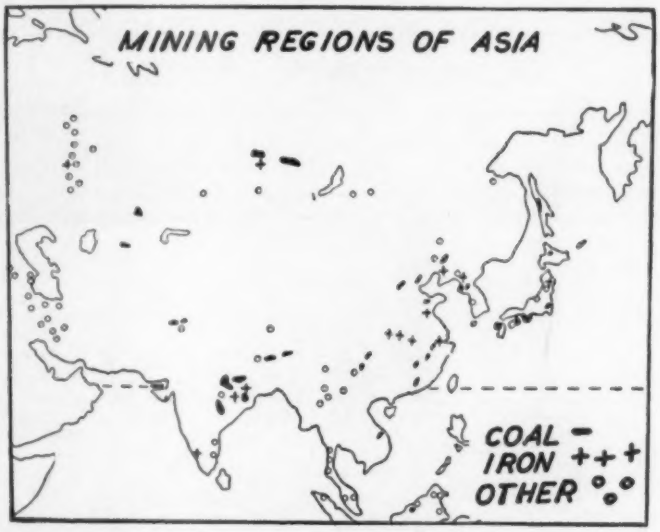
Ore fields and the movement of iron ore in Europe. A, Lorraine iron fields; B, fields of Northern Sweden; C, fields of Northern Spain. The numbers on the different countries indicate exports (E) and imports (I) in millions of tons. (Courtesy C. F. Jones.)

modern steel industry depends on the whole complex of the factors previously discussed. Furthermore, the trend in steel technology indicates that future progress will be in alloy steels. These can only be demanded and used in well advanced industrial areas. This trend means that a steel center must be able to attract a great variety of metals. The United States at present must import forty kinds of ore from fifty-seven countries for alloy purposes. It is much more likely that

centers already developed will be able to secure and use these various ores most efficiently providing, of course, that international relations are conducted so as to keep the good-will of the nations of the world.

Returning to our original thought involved in Siegfrid's discussion of present world industrial trends, we conclude that relatively only a few nations can hope to develop such complex fuel-metal-machine civilizations as we know in the United States and Northwestern Europe. But, before we

FIG. 20.

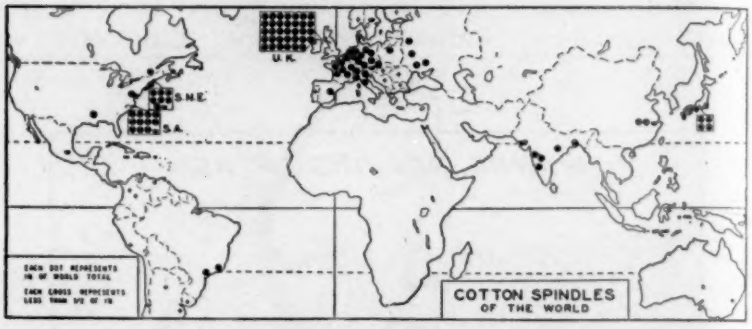


The steel industry of Asia is handicapped by poor grade of ore and by wide geographic separation of raw materials. (Courtesy C. F. Jones.)

leave the feeling that this all leads to serenity it might be well to point out that the base on which this structure rests is one of expendable resources. They are continually being used up and though we may expect improvements in technology to permit the profitable use of lower grade ores we nevertheless are led to see the great value in intelligent conservation of our natural resources. Also, a large percentage of the world's wage earners are engaged in labor-market oriented industries.

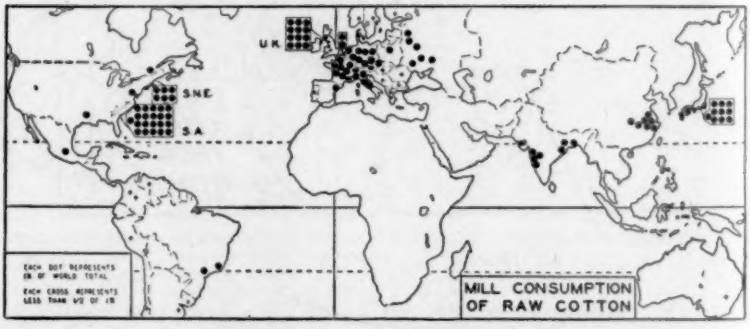
The textile industries were the pioneers of industrialization as it spread around the world even as they were the first to adopt the factory system. Since the World War these industries have developed rapidly in Japan, India and Brazil. This was a development to be expected although the early

FIG. 21.



Europe and east central North America have 84 per cent. of the world's cotton spindles. (Courtesy C. F. Jones.)

FIG. 22.



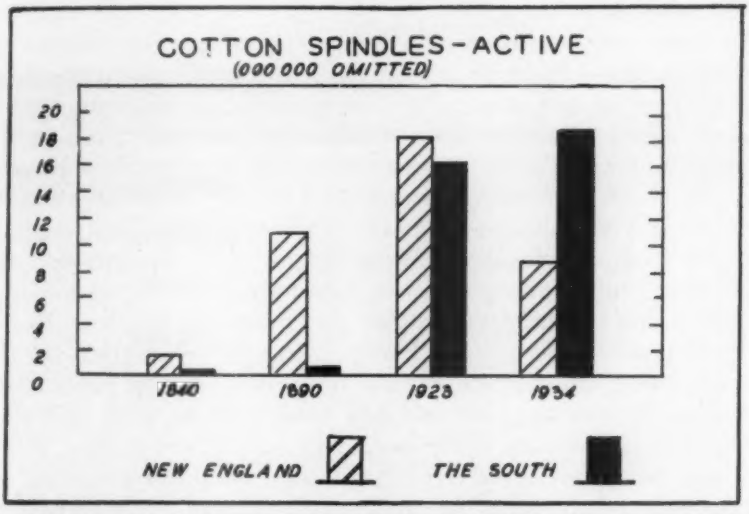
Europe and east central North America consume in their textile mills about 73 per cent. of the raw cotton of the world. (Courtesy C. F. Jones.)

localization of the industry in Lancashire and New England obscured the natural tendency of diffusion that characterizes the industry. What are the fundamental factors that determine the distribution of cotton textile plants (Figs. 21, 22)?

The raw material of the cotton textile industry is grown mainly in three widely separated regions of the world—the

southern United States, India and China. It is easily handled, does not spoil and its value in relation to its bulk permits it to be transported economically over long distances. Its price tends to be established in world markets. Most of it enters into the finished product in contrast to the ore and coal that are used in the manufacturing of steel. Therefore, the characteristics of the raw material permit the processing of cotton to take place long distances from its source. Before 1880 the cotton goods industry in the United States was largely located in southern New England (Fig. 23). This

FIG. 23.



The dominant position of the South in active spindles in 1934 is in sharp contrast to its rank in 1890. (Data from U. S. Department of Commerce.)

was due to the early accumulation of capital, especially important when capital was immobile; to the relatively small importance of agriculture in New England as contrasted to its dominance in the South; and to the more direct influences of water power and climate. Many textile mills in New England were built before 1850. At that time water power was used to turn the machines. Direct shafts and belting determined the size of the mill that could be economically built. This size was small. Therefore, regularity of water supply and

many mill sites on the same or several streams were necessary for a large output. New England possessed these conditions to a high degree. Water power gave New England a distinct lead in the manufacture of cotton cloth. After 1850 steam was used for power. This gave an advantage to mill sites where coal could be placed cheaply. The many good harbors along the New England Coast provided these conditions. Also, the speeding-up of the spinning operations had created the problem of keeping the amount of frictional electricity in the threads at a minimum. This could best be met by placing the mills along the humid coast. Local interest and ready capital were also important in determining the particular coastal sites of the mills.[19]

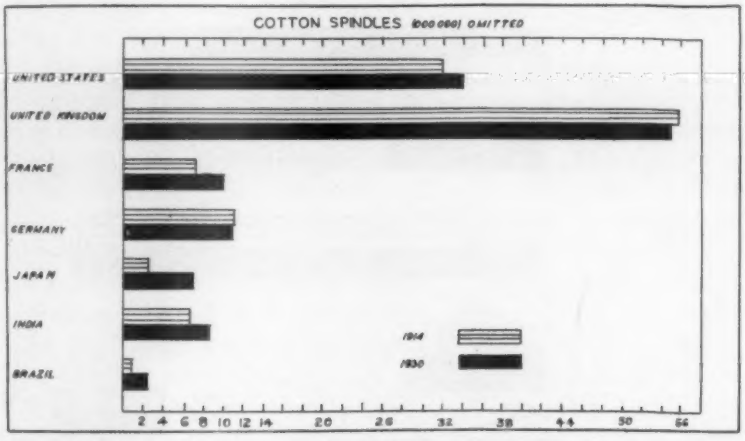
After 1880 the power factor became of less importance in the location of the mills as electricity was used. This could be developed by either water or steam power and with the power plant divorced from direct contact with the machines, mills could be located with less regard to this factor. Power costs made up an increasingly small part of the total cost of production. While these power developments were releasing the plant from particular site conditions, new inventions, especially ring spinning and the automatic loom, were making the machine operations simpler and more automatic. These developments permitted lower costs of production as it encouraged continuous rather than intermittent operation and made possible a cut in labor costs because little skill was required and women could do a large part of the work. With power being available over large areas and the purchase of raw materials possible over extending areas as world transport improved, the dominant factor in determining plant location became cheap labor. Wages, running hours, and labor legislation were controlling factors. Regions that were not engaged in manufacturing, regions just opening up and nations in which the whole complex of geographic and social conditions had led to low labor costs, offered the best advantages for the making of low and medium quality cotton goods. Localization factors permitting the industry to be easily established and home markets providing a demand

[19] Keir, Malcolm, "Manufacturing," A Volume of Industries of America, The Ronald Press Company, New York, 1928, Chapters 13, 14, and 15.

readily led to the enactment of protective tariffs (Figs. 24, 25).

The natural result of the technical developments of the industry, the character of the raw material used, and the wide area over which satisfactory geographic conditions prevail is seen in the equatorward migration of cotton goods manufacturing.[20] It is safe to say that geographic and cultural conditions will give the advantages of low cost production in labor-market oriented industries to the nations of warmer climes. The securing of capital and machinery presents no

FIG. 24.



The graph shows the extent of the equatorward migration of the cotton texcile industry during the period 1914–1930. (Data from U. S. Department of Commerce.)

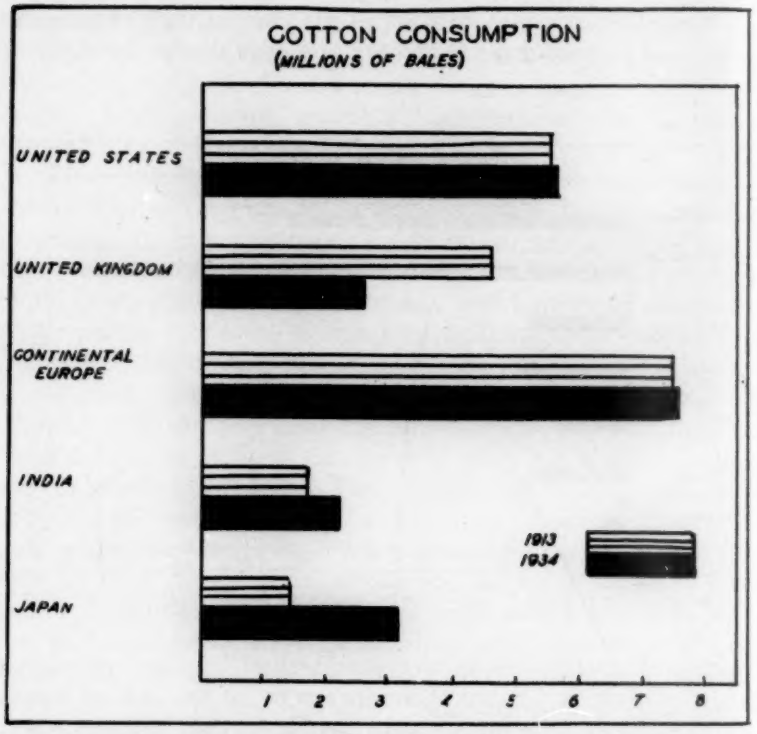
serious obstacles. Both are mobile and at least in certain areas, especially Japan, there seems to be no lack of managerial ability. We may fairly conclude that the trends in this labor-oriented industry point to the continued development of these forms of manufacturing in the countries outside of the machine-fuel-metal districts of Northwestern Europe and the United States. Such industries will develop to a higher degree and will assume a place of greater world-wide importance than can the fuel-metal industries in the same

[20] Huntington, E., Williams, F. E., and Valkenburg, S. van, "Economic and Social Geography," John Wiley and Sons, Inc., New York, 1933, pp. 523–526.

areas. Siegfrid's fears are thus based on actual trends in terms of labor-oriented industries rather than on developments in the raw material-metal oriented industries.

From a national point of view, and from the point of view of such declining areas as New England textile centers there can only be one conclusion in regard to these trends. We

FIG. 25.



The shift in the consumption of cotton since 1913 is in favor of Continental Europe and The Far East. (Data from *Yearbook*, U. S. Department of Commerce.)

must realize that world difficulties are part of a trend of increasing industrialization in relatively backward parts of the world with the consequent effects on the already established industries of the more mature manufacturing nations. The sections, as Northern England and New England, must understand that the dominance of their industries was based

on a passing phase of economic development. The advantages growing out of an early start and past technological methods cannot endure permanently. This development has proceeded further, and over a larger number of industries in the older and smaller nations of Europe than in the United States. They have recognized this condition and have attacked it in the only intelligent manner possible—by careful study of all the factors, geographic, social and economic that determine the growth and decay of a nation. We have been especially laggard in one aspect of such a study, namely, the part geographic conditions play in the productive system of the nation. We can delay matters no longer, or as it is more commonly stated, the frontier is gone and we must readjust our whole system to the resources that we now have and can secure by trade. We are making beginnings but not the progress that can be made as soon as we recognize the value of regional studies and the part natural resources play in determining the characteristic economic life of the nation.

To consider these remarks as a disparagement of the notable efforts of such organizations as the New England Council, the Philadelphia Tri-State Board, and Chambers of Commerce is to misinterpret them. To understand them as a plea for further and continued application of geographic methods of description and analysis in planning is to appreciate a fundamental weakness in our present methods and to realize that perspective and training is necessary for leaders in this type of work. Planning is in the embryonic stage. Let us rear it on a diet of facts in their true perspective. Many current problems could be cited as examples of the need for careful scientific appraisal of all the factors that determine the economic and social pattern of a region. We will use one of these for purposes of further illustration—the question of decentralization.

The first formal discussion of decentralization is found in Sir Ebenezer Howard's book, "Tomorrow."[21] It has been tried in several places. One of the most successful cases is that of Welwyn, England. The key principle to Welwyn is that there are tremendous advantages to be gained by

[21] Howard, Sir Ebenezer, "Tomorrow," S. Sonnenschein and Company, Ltd., London, 1898.

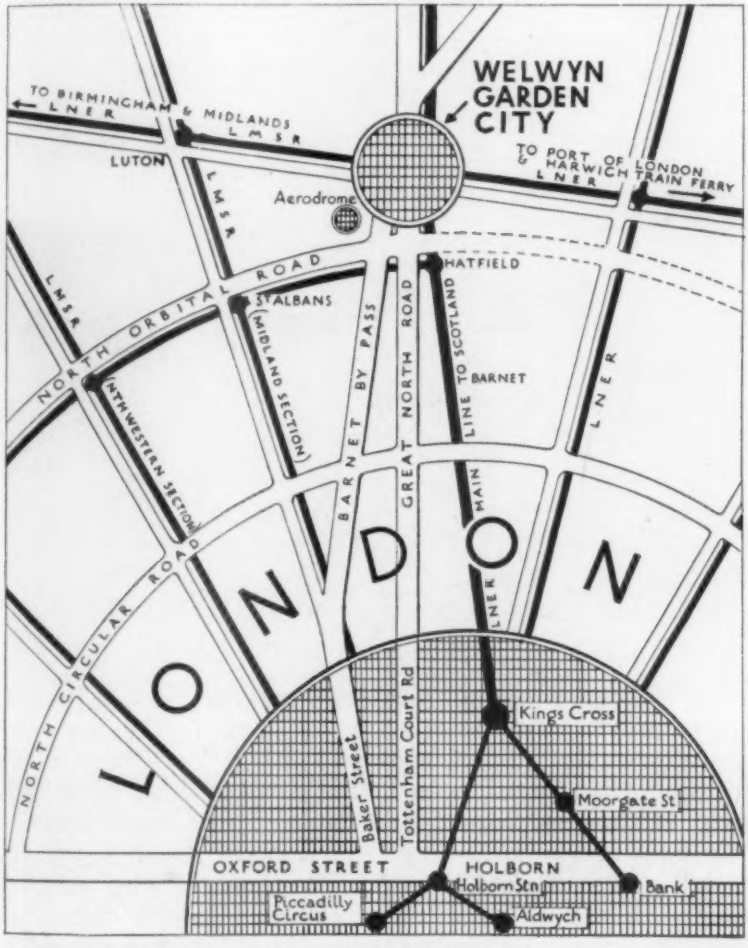
"decentralizing" industry as well as population. By "decentralization" is meant the building of new factories, workshops, offices, and homes in the outer part of the region surrounding a great city, instead of in the center or immediate outskirts. Welwyn has been planned from the beginning to be a separate city with definitely allocated areas for industry, trade and residence, with a more or less self-contained and complete provision of all the services demanded by civilization today and a definite corporate civic life of its own (Fig. 26).

FIG. 26.

Welwyn is not a government or municipal undertaking. It has not been aided by any official policy of decentralization. The land was bought privately and building begun in 1920 by a company founded by Mr. Howard, without statutory powers and with no influence over the movements of industry or residents except as it could gain by advertising or persuasion. The situation chosen for the town was as near to Central London as was consistent with the idea of self-contained towns (Fig. 27). There was necessarily a period of dependence on London but today it is a self-contained town. The first factories were opened in 1925 and in 1935 there were 40 industries in Welwyn. They included constructional steel work, brick making, and iron-founding;

face cream, silk dresses, confectionery; electric water heaters, and grinding wheels and tiles (Fig. 28). The population of the town is just over 10,000—one-quarter of the total for which the town was originally planned. Of the 4000 persons employed about four-fifths are engaged in Welwyn industries

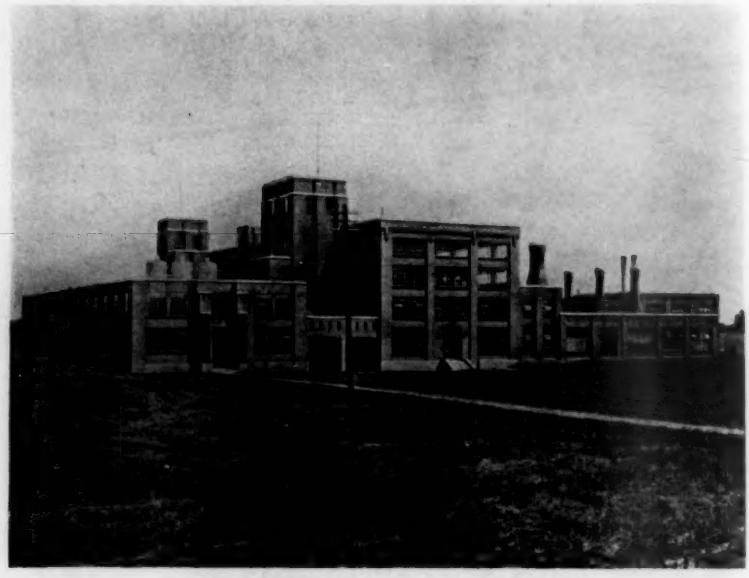
FIG. 27.



From Aldwych, Piccadilly or Bank by rail via Kings Cross, or by road via Barnet By-pass or Great North Road; about 45 minutes. From Kings Cross by rail: 28 to 40 minutes. Welwyn is outside the area of chronic traffic congestion. Quick rail and road deliveries can be made to all parts of the London area and the rest of Great Britain.

and businesses and the remaining fifth work elsewhere, mostly in Central London.[22] Industry does not spoil a town so well planned as Welwyn. The productive value of good housing and cheerful, healthy living conditions is gaining increasing recognition everywhere (Fig. 29). We are learning to place good living conditions on an equal footing with technical facilities as factors contributing to efficient production in industry.

FIG. 28.



Norton Grinding Wheel Factory—Welwyn.

In the United States today decentralization is a popular subject and a greater knowledge of it is vital. The term has varied meanings in this country. There have been a few projects of decentralization in the sense that we have been using the term. Daniel B. Creamer, in a study entitled "Is Industry Decentralizing?" in Bulletin Number 3 of the study of Population Distribution conducted by the Industrial Research Department of the Wharton School of Finance, defines the various types of industrial decentraliza-

[22] "Welwyn," Welwyn Garden City, Ltd., Welwyn, England.

tion that have occurred in this country since 1899. This represents the latest statistical study of decentralization in the United States. It was preceded by another general study by Tracy E. Thompson, entitled "The Location of Manufacturing, 1899–1929." [23] Both studies mark important milestones in the consideration of this problem.

This population map constructed by Thompson shows so-called areas of primary and secondary concentration. Twenty-nine per cent. of the total population and 43.8

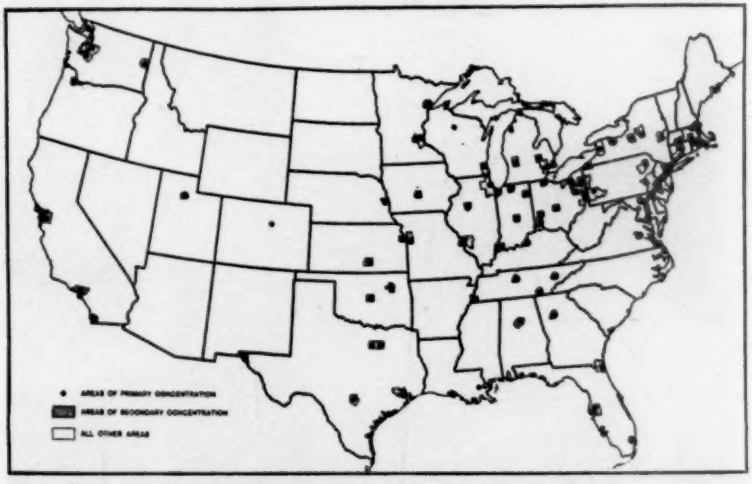
FIG. 29.

per cent. of the wage jobs of the nation are located in 93 cities with a population of over 100,000 each, called primary areas (Fig. 30). Secondary areas, composed of the remainder of the areas of those counties within which cities of 100,000 population are located plus 47 counties delimited as "industrial counties" by the census contain 14.5 per cent. of the total population and 21.1 per cent. of the wage jobs. Since 1899 there has been a slight increase in wage jobs in the

[23] Bureau of Census, U. S. Department of Commerce.

secondary areas and a slight decrease in the primary areas. Creamer uses a more detailed method but both conclusions are about the same on this phase of the subject. Creamer says, "The results of this investgation can give but little comfort to the extreme decentralizers. They must derive what satisfaction they can from the unmistakable evidence of the decline of the principle cities as manufacturing centers from 1899–1933." The recorded changes represent for the most part

FIG. 30.



The areas of primary concentration include 93 cities with a population of over 100,000 each. Secondary areas are composed of the remainder of the areas of those counties within which cities of 100,000 population are located plus 47 counties delimited as "industrial counties" by the census. All other areas include the remainder of the country. Forty-three and five-tenths per cent. of the population of the nation and 64.9 per cent. of its wage jobs are located in the combined primary and secondary areas. (Source: "The Location of Manufacturing, 1899–1929," Tracy E. Thompson, Bureau of Census, U. S. Department of Commerce.)

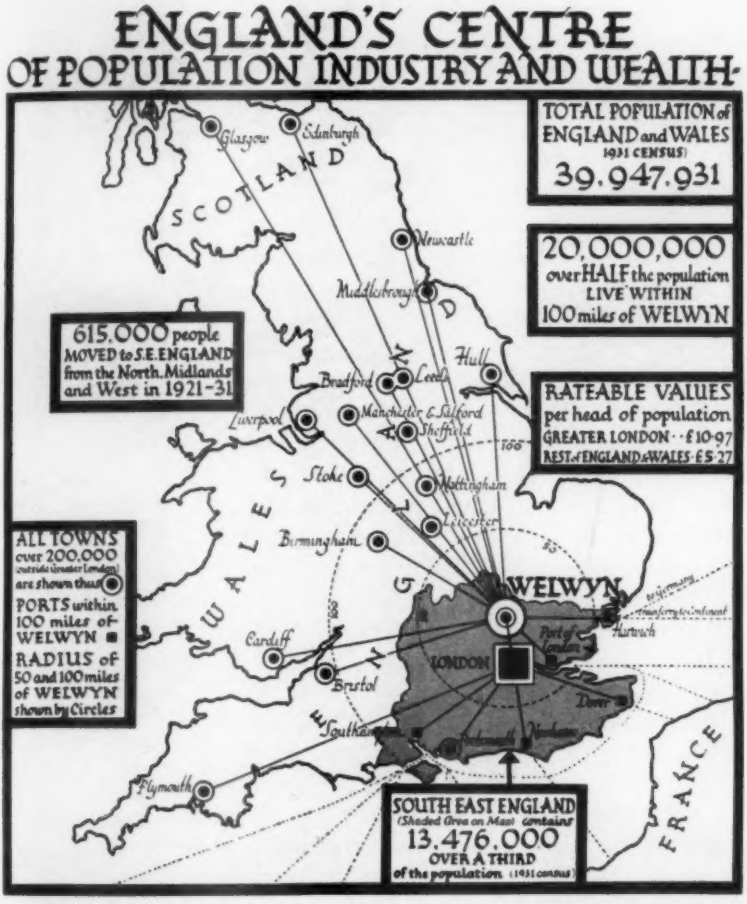
not a scattering of factories up and down the length of the land, but a gradual and limited filling out of the industrial pattern within the major manufacturing regions.

Whether or not we are to have the Welwyn type of development or the type of "diffusion" of industry as evident at present in the United States, the lessons learned from a study of Welwyn must not be lost.

With the objective being a planned town the Welwyn founders had to ask—where is the best place to locate a town?

The importance of the answer to this question is obvious. The starting of a factory or a town is the one chance to go "all out" for maximum efficiency, maximum profit and

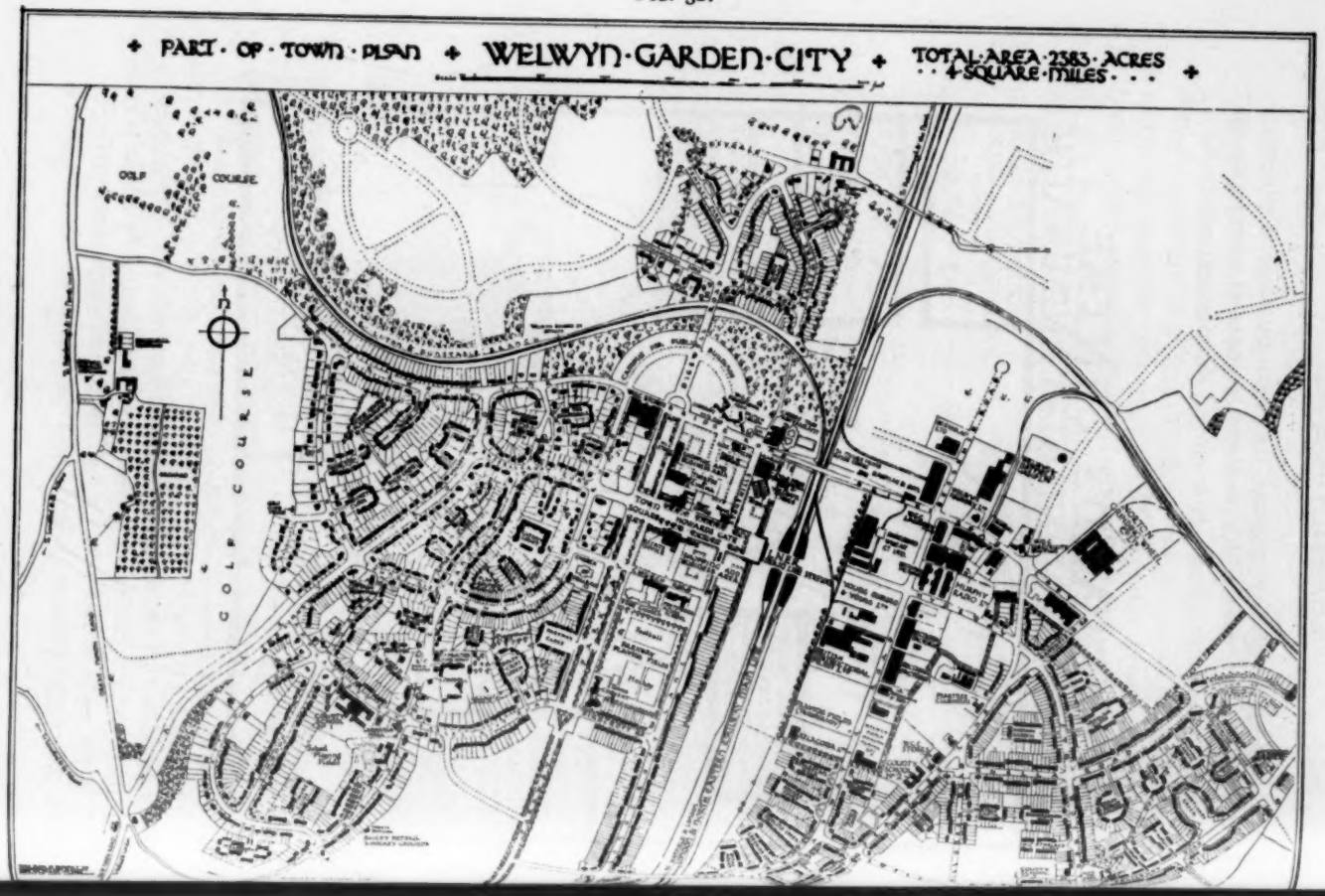
FIG. 31.



Welwyn is advantageously located with respect to England's population and markets.

satisfaction. In answering the question "where?" the general region in which the plant is to be located must be chosen on the basis of a broad survey. Climate, transportation facilities, markets, power, labor, and political factors must be

FIG. 32.


PART · OF · TOWN · PLAN
WELWYN · GARDEN · CITY
TOTAL · AREA · 2383 · ACRES
+ SQUARE · MILES
GOLF COURSE
GOLF COURSE

considered. Then the combination of these factors become important. It is as bad for an industry to move to the wrong town as it is for the town to have the wrong industry move in. The preliminary economic-geographic survey indicated that a section outside of London was the best in the United Kingdom for the type of town planned (Fig. 31).

The success of this experiment may be explained first of all by the realization that the careful study of industrial location presents the possibilities for intelligently predicting the future development of an area.[24] Secondly, by recognizing that a successful industrial structure is necessary for fruition of this type of plan. Such an industrial structure includes the proper location of the industry to raw materials and markets, the lowest cost location of the plant in the general region where it is to be, and the most efficient relations between the manufacturing, commercial and residential sections of the town (Fig. 32). The study and careful weighing of the forces that make for successful industrial growth showed that there was to be a more rapid increase of factories in southern England. Welwyn development is a concomitant of this "Londonward" migration of industry. Statistics show that factories are being built at a much greater pace in the London region than in any other. The "depressed areas" of northern England, based on textiles and "heavy industries" are losing out to these newer areas (Fig. 33). The explanation of this trend lies first in the nature of the industries. The new industries are largely market oriented ones such as cosmetics, prepared foods, and radios. In England the largest market is the London area, while a location like Welwyn's permits easy access to northern England. These industries do not require large amounts of power, or special types of labor. They do need many means of transport and the London area has all kinds. Thus Welwyn's success is in no small part due to its location, and to other advantages that it offers to new industries developing in England. This suggests that healthy

[24] The need of, and the practical results from, the careful scientific study of plant location has been recently clearly stated by a leading American engineer. See "Industrial Surveys," An Address before the 18th Annual Meeting of the Pennsylvania State Chamber of Commerce delivered at Harrisburg, on January 30, 1935, by Charles Penrose, Vice-President, Day and Zimmermann, Inc., Philadelphia.

decentralization can take place under the direction of private enterprise when done scientifically. This is an important fact for America to realize today.

FIG. 33.

The market-oriented industries of the United Kingdom have been moving to the London area in recent years.

The rise of Welwyn shows that towns are not necessarily a natural growth that men cannot create or control but must accept. Towns can be designed and created. The ease with which this can be done increases as transportation facilities increase. It suggests that towns do not grow due to some mystical 'law' of town growth. This is not to say that present

towns or future ones are not dependent on the general and specific geographic and socio-economic institutions of a particular region. It does say that when we understand the proper part that each force of the whole environment—social and natural—plays in the growth and decay of a city we can guide it into the best channels known at the time. It also suggests that the key to town growth is the industrial structure of the town. We need more men trained in the sociological-economic angle of the problem than the architect-surveyor angle. Nations and scientific institutions need to promote information and analysis along these lines rather than applying remedial measures to dying industries and decayed regions.

What further meaning do these conclusions have for current problems requiring planning? We have noted the factors that have encouraged the movement of a certain percentage of the cotton goods industry from New England. By no means all the cotton manufactures left need to go, but enough have gone to lead us to believe that permanent unemployment is the prospect for many able and intelligent citizens of the less fortunate towns. As a nation we are just beginning to recognize the seriousness of the unemployment problem. We are applying some intelligence to its solution, but only a small modicum of the knowledge and ability available. We are merely beginning when we are able to determine the number and character of those who are permanently displaced from the industries of a particular town. What are we going to do about it? There are three possibilities. We may provide relief for them and allow normal forces to work themselves out as best they may. It is unthinkable that we should proceed along this route much longer. What else can we do? We can develop new industries in these towns. When this cannot be done profitably there is only one other possibility. That is to have responsible agencies suggest other regions where there are better opportunities for the stranded population. We can do this only when we recognize the remarkable possibilities for appraisal of present and future regional trends in the economic-geographic approach to social problems.

We have reached a stage in the evolution of our national life when the results of scientific research must be consciously

related to our social life. Modern geography offers a most valuable method for the coöperation of the social and natural sciences in the solving of our most fundamental national problem. This problem may be stated as the proper and more rapid correlation of all the changing factors operating in a region as science continually evolves new techniques that require new social adjustments.

Professor Julian Huxley, in an article entitled "Can Sociology Become a Science?", states, "To get full value out of social science, it is essential that the public should be able to grasp the ideas of multiple causation and multiple effect." [25] Raymond Pearl, in an article called "Biology and Human Progress," says, "In the field of human biology the admitted and crying need is for adequate synthesis of existing knowledge." [26] These statements by outstanding men in the fields of social and natural science crystallize in a few words the trend that educational leaders are attempting to interpret. Orientation and integration courses are being considered as essential to develop perspective and a broad outlook on life on the part of the college man.

A corresponding development and recognition of the same general conditions takes place when such organizations as the Natural Resources Board, the New England Council and the Regional Planning Federation of the Tri-State Metropolitan Area of Philadelphia are set up. Both of these developments are destined to continue on an ever increasing scale. Although we as a nation have been inclined to accept our fabulously rich geographic environment much as a matter of course, Arthur Pound, in his book "Industrial America" recognizes its significance when he states, "The characteristic expression of contemporary America is American industry. The geography of a continent and the enterprising qualities of a pioneering people have combined to make the scope and consequence of the great businesses of America unique in social history." [27] The mobility of capital, the brief ad-

[25] Huxley, Julian, "Can Sociology Become a Science?", *The Fortnightly Magazine*, August, 1935.

[26] Pearl, Raymond, "Biology and Human Progress," *Harpers Magazine*, Harper and Brothers, New York, January, 1936, p. 235.

[27] Pound, Arthur, "Industrial America—Its Way and Work," Little, Brown and Company, Boston, 1936.

vantages to be gained by a new invention because of the speed at which the latest types of machinery migrate to all parts of the world, and the increase in semi- or un-skilled operations in modern industry gives greater significance than ever before to geographic conditions and managerial skill as determinants of industrial growth. Add to this the disappearance of our frontier and the conditions of our foreign markets and one cannot fail to realize the imperative need for greater study of our geographic heritage.

There is but one inevitable conclusion. Whether in the civic organizations set up to help us plan, or in college curricula and general fields of knowledge, geographic facts, methods and perspective will be, and must be, used to a greater and greater degree if we are to attain the plane that our social institutions are capable of inherently.[28] More particularly, Geography possesses in itself high disciplinary value and the student of Geography comes to recognize the various modes of life followed in different parts of the world as natural corollaries of contrasted environmental and institutional conditions. While appreciating the utility of dissimilar environment, he at the same time realizes the economic, social and political problems that grow out of man's present or past adjustment to the natural environment. This leads to a sympathetic insight into the lives of people who inhabit lands unlike his own and in measure with this perception he becomes a more trustworthy member of his own society and, at the same time, a citizen of the world.

[28] It may be of interest to readers of the JOURNAL to know that the author, while visiting and speaking on the subject, "The Importance of Economic Geography," at a leading eastern college of engineering, learned that serious thought was being given to the development of courses in Economic Geography. If we accept the definition of Engineering in the mural inscription in the Engineering Societies' Library in New York which states, "Engineering—The Art of Organizing and Directing Men and of Controlling the Forces and Materials of Nature for the Benefit of the Human Race," it is clear that a subject that studies the causes governing the location of industry would be of highest value to an engineer. He must be gifted with insight into modes of life followed in various parts of the world, he must understand the part that technology plays in the distribution of industry and he must possess a wide perspective of industrial evolution if he is to work successfully in a world where more planning is inevitable. Training in the facts and methods of Economic Geography will carry him far along this road.

A New Power Supply System for Electric Clocks.—M. S. MEAD, JR., AND J. H. REED. (*General Electric Review*, Vol. 39, No. 12.) For its office and time card clocks, the General Electric Co. at Schenectady several years ago installed a centrally regulated time system for which the power supply is initially direct current drawn from the d.c. lines of the plant. In order to use synchronous motor clocks in this system, it had to include equipment for inverting d.c. to a.c. of an average frequency that would remain substantially constant. This was accomplished by utilizing a synchronous converter operated as an inverter, the speed of which was regulated by a master clock and the a.c. output of which was distributed to the clocks. Recently, however, a new type of source of accurate frequency power was developed for use in systems where unregulated a.c. power or d.c. power is only available. The unit is called a fork controlled thyratron tube inverter. It is capable of operating as many as 125 clocks and is comprised of an oscillator, an amplifier, and an inverter that are interconnected. The thyratron tube inverter is especially suitable as a 60-cycle power supply, and is quiet in operation with no moving parts. The reason that a clock load is particularly suitable for an inverter is that this type of load has a constant impedance which promotes stable operation and constant voltage output of the inverter. The source of control frequency is a tuning fork oscillator with a buffer amplifier. The original objective called for an accuracy of one second per day, plus or minus, and the tuning fork oscillator was selected because it will insure this accuracy without resort to complications.

R. H. O.

PROGRESS OF THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.*

BY

DR. ELLICE McDONALD,
Director.

The Biochemical Research Foundation is almost exactly one year old, although it existed for eight years previous to this as the Cancer Research Laboratories. It has grown from one worker nine years ago to fifty-one people at the present time.

This lecture tonight is for the purpose of reporting the progress of the research during the last year, but to report the work of fifty people in detail is obviously impossible. So that you may see this, I have placed on the desk the accumulated reports from the workers for the past year. These measure fourteen inches through and weigh ten pounds. I have calculated that to go into the details of all these reports would take forty hours of lecture.

Ours is more indeed than a research organization: it is an experiment in research organization itself. We have had the opportunity, owing to our growing development and progression, to make certain adaptations in research in general.

Chief of these is in connection with coöperation and correlation in groups. This is the modern phase of research and has not been due entirely to modern methods of organization, but has been forced upon research by the advent of quantitative criteria. In past time was the day of the individual genius, the "prima donna" type of worker who by his qualitative observations developed new paths of knowledge. He was an observationist as contrasted to the experimentalist of today and recorded his observations according to his own judgment. The successor of the observationist is the statistical experimentalist who not only observed, but recorded his observations in a quantitative manner making it possible for another to unify them and to go on to further experiments from that point. An example is the study of astronomy which, when

* Presented at the Stated Meeting held Wednesday, December 16, 1936.

Newton discovered the law of the movements of the celestial bodies, then went on to exact recording and, amongst other things, made the Fels Planetarium possible. So in the consideration of present day research, particularly in a subject with so many variables as the biochemistry of the human vital system, it is of immense importance to correlate these variables to the exact sciences of chemistry and physics.

We therefore began our efforts by developing a department of chemistry and after this, a department of physics and a department of cytology. The cell is the unit of life and it seemed as if cytology should have been developed first, but it was thought best to develop chemistry and physics and orient these to cellular processes rather than develop cytology and instruct the cytologists as to the more exact sciences.

We have now three departments, chemistry, physics and cytology, all correlated and intercommunicating with each other. Indeed it is hard to draw the line where one ends and the other begins. So much of chemistry is dependant upon physical apparatus and exact physical measurement, and so much of physics is dependant upon chemical interpretation that all boundaries between the departments of science are disappearing. Cytology indeed is become more and more the chemistry of the cell.

We are studying in detail the bacterial enzymes, methods of determination and kinetic studies of gelatinase and cathepsin, activation and inhibition phenomena of these enzymes, a detailed study of the changes produced in proteins by proteolytic enzymes, factors involved in the production of proteolytic enzymes by bacteria, the influence of kidney glyoxalase on the amino acids, the influence of enzymes upon cysteine and glutathione, the purification of kidney glyoxalase by adsorption and precipitation methods, the course of carbohydrate oxidation and its ability to resynthesize carbohydrate from lactate and pyruvate, a detailed study of succinic oxidate and the relation to metabolism of cancer tissue, a study of the oxidation-reduction dyes in catalyzing the oxidation of carbohydrate intermediates and their effect on isolated enzymes, a study of peroxidase as an example of an oxidative enzyme.

In the chemical department, in addition there is a study of

the phosphate esters and phosphatases including the development of a micro-method for the determination of amino-ethyl-phosphate in blood and tissues, a question whether amino-ethyl-phosphate is specific for tumor tissue, the study of normal and tumor tissues for the presence of a phosphatase specific for the hydrolysis of amino-ethyl-phosphate, the synthesis of amino-ethyl-phosphate for use in animal experimentation, the question of acceleration of tumor growth with amino-ethyl-phosphate and related compounds.

We are also studying certain extracted liver fractions which protect against liver necrosis from chloroform and carbon tetrachloride poisoning and the ability of these liver fractions to accelerate tumor growth, the attempt to purify and isolate active liver fractions for experimental treatment of certain liver diseases.

We are making by means of the Linderstrøm-Lang micro enzyme technique a histo-enzymatic study of the distribution of the proteases, dipeptides, aminopolypeptides and proteinase in kidney with substrates of glycyl-glycine, leucyl-glycyl-glycine and edestin respectively, preliminary studies on the application of the micro-method to the determination of carboxy-polypeptidase, deamidase and anti-glyoxalase followed by the histo-enzymatic studies of these enzymes in kidney, the application of the micro method to the determination of dipeptidase carboxypolypeptidase and glyoxylase in the kidney fractions.

We are studying by the manometric method the effect of biologically important substances (vitamins, hormones, sulphydryl) on metabolism of tissue slices, the effect of glutathione on tissue metabolism such as the effect on the Pasteur reaction.

We are studying the effects of radiation upon tissue metabolism and the detailed study of immediate and delayed effects of large doses of X-rays on the chemical metabolism of slices of normal and tumor tissues *in vitro* and a comparison of these effects done *in vivo* and a search for methods whereby artificially produced radioactive substances may be tested biologically.

All these chemical ventures are correlated each with another. A sub-department of micro-analytical chemistry

has been developed which will be of great use to all the other chemical work. The importance of minute amounts of substances in biochemistry is immense, often one part in 100,000 or one part in a million will produce profound effect. In the micro-chemical laboratory of four rooms with two trained men, it will be possible to analyze samples of 5–8 milligrams and make determinations to 6-millionth of a gram in favorable cases. The advantage of this micro-analysis in the determination and isolation of small amounts of biologically active substances will be great.

We are studying in an outside station the reactions in the blood of cancer patients and of psychiatric patients with the hope of developing some fundamental facts there.

In the physics department, we are studying with the Svedberg Ultracentrifuge, by the good will of the Experimental Station of the duPont company to whom this centrifuge belongs, the serum of cancer patients before and after treatment, the examinations of antigens and antibodies, the effect of various experimental measures upon proteins.

In the physics department, also is the study of the effects of X-rays on tissue metabolism and upon single-celled organisms, the effect of X-rays upon various chemical systems such as dipeptides, polypeptides, amino-acid fractions and other synthetically produced substances, the absorption spectra and chemical changes produced in chemical systems, allied to vital systems when treated by X-rays and ultraviolet light, animal experiments to attempt to explain the mechanism of radiation on tumors.

We are studying the physical and chemical properties of erythrocytes by their electrical characteristics in suspensions, the effect of hemolytic agents *in vivo* and developing knowledge about a system of suspensions of erythrocytes which may be used as a means to study any chemical or physical phenomenon of a biological nature.

We are constructing at the Bartol Foundation a cyclotron for the production of artificially induced radio-active substances for biological study. We have recently made a supersonic apparatus for destruction of cells so as to obtain their intracellular enzymes. We are making a new ultracentrifuge of the Beams type for the study and isolation of minute

amounts of biological substances. We are studying the absorption spectra and radiation effects on important biological substances.

In the cytological department, we are making various enzyme studies, the nuclear removal from malignant tissue by enzymes, the quantitative nucleic acid determination in the presence of protein, the effects of various enzymes on the nucleus of tumor tissue, a comparison of the action of different fixatives on tumor and other tissue in relation to their nuclear staining. We are studying the proteolytic enzyme producing bacteria in relation to their cultural characteristics on amino-acid and purely synthetic media and the alteration of the various forms of these bacteria. We are studying the effects of various growth stimulants on bacteria and their enzyme production, the effects of various dyes on the organs and their vital staining, the effects of the hormones on the growth of young animals, the various bacterial association in cancer tumors and a number of other minor phases.

The choice of projects is often a difficult one. The object of an experiment is to determine the existence of some effect; secondly, if it exists, to measure it, when it is measured, the significance of the effect should be considered and, most of all, the magnitude of the significance. The last is the most difficult of all. In order to do these things, the means at hand must be considered.

For this reason, research programs are often built up about a good piece of apparatus, something that can do and measure the results of experimentation such as the manometers, the ultracentrifuge, the cyclotron, for a few examples.

In addition, the capacity of the people involved and the probable time that will be occupied is of importance. Is the technique already available or must it be worked out? If complete success comes to the project, what do we then have and what further experimentation will it lead to? Can the facts which will probably result from the experimentation be correlated with other known facts? In that way it increases the value of both. How much time will it take and how is it correlated to the general program?

Choice of research projects should be slow and careful. It pays to consider them carefully and take counsel about them.

The mean should be between the brilliantly useless and the cheaply practical. If a matter is being well studied in another laboratory, it should be left to them for, in scientific research, duplication is a crime.

It is better to choose what can be well done with the means at hand rather than use a counsel of perfection which may take years to accomplish. Fashion in research affects laboratories as well as people and the tendency is for all to run in one direction following some interesting discovery and elaborating it. This is depressing to originality and should be forfended against. While men are working on one project, their thoughts should be prepared for some new phase in the future by discussion with them to arouse their interest in the future and in possible developments. They will then approach the new phase with eagerness and zest.

THE AIM OF THE FOUNDATION is to attach biochemical investigation to the exact sciences of chemistry and physics. Biological research in general is upon an experiment and error basis: this type of effort is quite all right if one does enough experiments. But the great difficulty in biological and biochemical research is the many variables and the absence of criteria. One alone of these might be easily overcome, but the combination presents a difficulty. In human biochemistry, all the factors which go to make up life present such a multitude of inter-correlating variables that deduction from experimentation is difficult unless the variables are connected with some phenomenon which can be quantitatively or statistically measured as in chemistry and physics.

Certain phases of research in living processes have fewer variables and better criteria. One example is the plant research, such as is being done so well in the Boyce Thompson Institute: here the criteria are the reactions of the plants themselves which can be measured and exactly recorded within a short time. So that here one may, temporarily at least, be satisfied with end results and not concerned with mechanism or the intimate processes of the reaction.

But with the study of the human organism and its vital system, the life of the subject is as long as that of the experimenter. So that it is not possible to study the reactions of the experiment by estimation of the processes of change which

result in the lifetime of the subject as it is possible to record end results in plants or in the fruit fly. *Ars longa vita brevis* is as true in biochemical research as it is in other phases of intellectual effort.

But it naturally suggests itself that, if human systems and human lives are so poor for the purpose of studying their own systems, that experimental animals, such as rats, mice, guinea pigs and rabbits, being mammals, might be so like in their biological reactions as to serve as test plants within bounds of reason. In general, this is not so, although such experimentation is of value. There are so many differences in reactions, life span, diet, species, etc., between man and the experimental animals as to reduce their value in research as being an analogous system to the human vital one.

This is being more and more borne into my mind and I find I come to place less and less reliance on the results of animal experimentation and am less prone to carry over from it, as a presumably analogous system, as applicable to the human vital system. An example of this is transplantable rat cancer which morphologically is so like human cancer as to make it presumable that the vital reactions would be similar. But it is found, while cellularly they look alike under the microscope, biochemically there are great differences. And after all, why should they be alike? The span of life is three compared to 70 years; the tumor grows much more rapidly, the character of the reactions of the vital fluids is different, etc.

This is an example of an analogous system where it is incorrect to consider the results as being true for the human vital system. Analogous systems in research are very pretty in theory but often false in results. Such study is often of great value in working out techniques to be later applied elsewhere and giving leads for further experimentation, but it should be remembered that analogous systems are merely analogous and this is very easy to forget. In yeast metabolism, which is very like the metabolism of the cancer cell, and, for that reason, very useful to employ in working out technical methods, lies an example; no one will really maintain that they are chemically the same. That they are different is easy to forget in the absorption of experimentation and so this illustrates one of the dangers of the analogous systems as such.

With attempts at exactitude, comes the effort to put biochemical research upon a mathematical basis and this, at the present time, offers some fallacies. It would be ideal to apply the mathematical method to biological research, but it is usually only possible now by ignoring some of the many variables. The results only illustrate the fact that, when defect of data is supplemented by hypothesis, the result will vary with the nature of the hypothesis assumed. If the principles of the theory of probabilities guide us in the selection of these hypotheses in biological research, the result is the more dangerous because the exactitude of mathematics is such as to make us believe that the final solution is truth, while this solution is based upon defect of data and scanty consideration of the variables. Mathematics may be a language, but, in biochemistry, results are usually better stated in a few plain English words.

The difficulty of the biochemical field compels us, in order that advance may be systematic, to correlate our variables with the exact sciences, particularly chemistry. When this can be done research goes forward with records which are of value for continuing sequence of further experimentation upon a quantitative and statistical basis and not dependant upon judgment and memory as is a good bit of biological research.

This correlation with chemistry, while ideal, is often difficult and indeed the area of study in biochemistry is usually limited by the possible amount of such correlation. The large number of variables in the vital system is less to be considered than the lack of exact criteria, for, if the latter is controllable, the variables can be sorted out in further work.

While this is the state of the biochemical science as it exists today after all it is dependant upon the observations of men and it is with these in the last analysis that the organization of research has to do.

Not all men have the research capacity, eager as some of them may be to do this character of work. The research power is an aptitude and is inherent, so if it is there, it can be developed. Desire to do research in a person who is unable to do it, from the particular character of his mind, is a most pathetic thing. The eagerness outstrips the capacity. In general, research men choose themselves because they seek out

places where they can fulfil their innate and overwhelming curiosity in regard to the structures and processes of the world. In the choice of men, the good old-fashioned rule that character should count for two-thirds and brains for one-third holds good. Our people are brought from all parts of the world and are chosen really for their training, special aptitude and background. The pupil of a great master always has a sympathetic hearing. But it is a poor pupil that is not better than his master and I recommend this to the hearing of our research people who are in the audience this evening. But in choosing a man, we don't want the old master but we want his best pupil. Most of our people are young men and we are willing to help in their training. They are young because in our laboratories coöperation and collaboration is our watchword and the young are more adaptable in this respect than those who are more fixed in their habits.

With good character, energy and adaptability, we really begin their training when they arrive in the laboratory.

The longevity of the research desire is only to be maintained by a constant struggle against the diffusion of the specialization of its energy. If the struggle is not made, the research desire succumbs after a brief flowering into the common processes of diffused thought. Other people unconsciously fight a man's concentration whenever it diminishes his use to them. Inside of himself, it is fought by the indolence of partial achievement and the incidence of new and extraneous interests which produce a diffusion of energy. Resting upon laurels, enjoying the rewards of partial achievement are fatal to research effort. Motive must overcome the scattering of life's energy into the little parts of less and less usable forms. Once the research desire, the intense curiosity as to the arrangement and order of existing things, is lost, it is rarely recovered. Nothing is more pathetic than the burnt out scientist. The disillusionment of a goal attained should never affect the research worker. There are always new worlds to conquer.

For this reason, the research desire should be sedulously cultivated. The scientist must continue to be prodigiously interested. Research is strenuous because it involves no routine. Each day is a new opportunity and perhaps a new miracle. For this reason, it is often fatiguing.

My experience in research as such leads me to believe that the lone worker with research ideas has a span of about 3 years in which his ideas are prolific and vital. At the end of that time, it becomes the elaboration of past detail and the continuance of repetition in *minutiæ*. Not all fall into this exact category but, in general, I believe this to be true. In our laboratories, immediately a man comes to us we attempt to enlarge his vision and extend his horizon, by interesting him in other phases of work, in other sciences, in other methods of attack upon scientific problems. This prevents the dampening of the stimulation to which the lone worker is subject. This reëducation, so to speak, is not a conscious thing, but the man is caught up into the spirit of the diffusion of knowledge which is present in our laboratory and it is pleasant often to see the flowering of his vision. In research, there is an imaginative impulse and the greatest research worker is he whose intuitions most nearly happen.

No splendid isolation is possible for the scientific worker. On the contrary, it is one of the gravest dangers which besets the specialist and specialists we must all be today. The man who tends to do everything will never achieve anything. If the mathematician, the chemist, the physicist, the biologist, the engineer and others lose contact, their separate progress is likely soon to come to an end. Many gaps in the uneven front of research today are represented by unexplored fields which lie between the activities of two or more branches of science. These gaps can only be filled in by the interchange of ideas from day to day and over a long period of time because it is difficult for scientists in different fields to learn the *patois* which each speaks. Often the lack of interest of the specialist in problems which lie aside his own domain is due to a lack of understanding of the language in which the other scientist is speaking. Mechanical-mindedness is a peril to which the scientific worker and above all the specialist is exposed even more than his fellow men. Team work and coöperation are the only methods of avoiding this depression and encouraging receptivity to new ideas. Vision and scientific imagination are the most important things in research. "If there be no vision, the people perish" and, if there be no vision in the scientific laboratory, the results are poor.

Innumerable trifles collected in an orderly mass although contemptible individually may, by vision and imagination, contribute largely to knowledge. Research requires more than patience, dexterity and exactness, necessary as these are, now since the present criteria are more quantitative than qualitative. An army of excellent but very ordinary people are at present carrying on research into the *minutiæ* of unimportance, but these are required to prepare for the exceptional man by whom real advance comes. Where would the world be without such exceptional men as Pasteur, Newton, Franklin, and other great men whose vision illumines the whole subject so that specialization could take it up and further elaborate it. Advance comes through the exceptional man.

Research is a demanding occupation. Self immolation is really a necessity. One must think about the problem all the time in a sub-conscious way. As Lord Kelvin said, "I think about the problem all the time and I gather all the information I can get about it and then when I am perfectly saturated with the subject and think about it all of the time, at some point my mind takes a mortal leap past all the facts." This is research imagination.

Teaching is an effort which detracts quite consciously from the concentration upon research. The patience, dexterity and decision demanded in research today require so much of a man's time, interest and concentration that, if teaching is added to it, one or the other must suffer. The investigator of facts, the man with real creative ability, should be free from other claims on his time so far as possible. The present practice of mixing teaching and research is inefficient from the point of view of research. A much superior type of research would be obtained if the two were entirely separated and made entirely separate organizations. Research, as it exists in Universities, suffers from this handicap and the teaching in the Universities also suffers from the handicap so that Universities no longer give the preparation for good citizenship which it should be the glory of a University to do. Universities have largely become institutions of teaching rather than centers of learning. Research cannot well flourish in this atmosphere.

Not the least important in the coördination of group work is the system of periodic reports. The advent of quantitative

criteria in research has made this a very necessary, important factor in the coöperation of different men and their groups. A number of different methods of reporting have been tried and the growing size of our laboratories made an ideal test plant for this purpose. We attempted to adapt reports to formulate on certain laws dependent upon the regularity of sequence of the activities of laboratories. It requires no technical knowledge to understand the statement that a business man's activities show a constant pattern no matter how varied the details with which he has to deal at times. It is difficult to describe them and still more difficult to analyze them but they are easily recognizable. They are, in fact, the constancies without which social life would be impossible. So, in research, there is the difference between the pursuing of research and thinking about the pursuing of research as a different process. We wished, therefore, to experiment in research organization itself and to consider the value of periodic systematic reports. In such reports, the first thing is to decide whether they should be instructive or informative; in our case information as to work done and the progress of plan was required. The reports were for the Director, the heads of departments, for the purpose of correlation with other departments, and for the information of any consultant who might be called.

The project is stated in general terms at the beginning, although in research it is never possible nor advisable to follow a rigid plan in an experimental project. The results from time to time modify the direction of experimentation. It is very like a military campaign. In past times, the type of war was the rigid phalanx of the Greeks. This was overcome by the light troops of the Romans used as an accessory to a fixed base. The Roman order was flexible. In the Second Punic War, the Roman Legion was incapable of coping with the real power of Hannibal's army placed in its elastically hinged cavalry wings. Scipio recognized the fundamental flaw in the Legion tactics and created an effective cavalry arm and developed a superior infantry pivot. And so on through the study of strategy. It is more and more the problem of concentration against action and a new understanding of the problems of alternatives, i.e. the adaptability of objectives.

So in the strategy of research, the years have shown a somewhat similar development, facing away from the rigid forms towards the variable efforts pivoting upon a strong base. This rests upon consideration in the choice of projects for our workers and one of the values of these reports is that the progress of the work may be maintained with a due consideration for the adaptability of objectives and possibilities of alternatives towards that place in the research where success is most likely to be obtained.

We have experimented in various periods at which these reports should be given, weekly, bi-weekly, monthly, etc. At first, the Director had a conference with the worker at a stated time when the progress of experimentation was discussed and the written report presented. With increasing size this was impossible and now the workers present their reports to the heads of the departments fortnightly. The Director has a stated conference with the head of each of the departments and one day a week when the department chief's report is given as well as the reports of the other workers discussed. This is of course in addition to many informal conferences and visits.

The reports state in brief detail the results of fortnightly work and appear upon one sheet of type-written paper, although they may be of greater length if so desired. These reports are of course in addition to the usual Laboratory Record Book. As most criteria are at the present time quantitative, the figures of such experiments are usually inserted.

The importance of this report is that it should give a record of the work without unduly hampering the worker himself. When a research worker is so organized or disciplined as to reduce his research capacity, the main object is defeated. The ideal is to get the record without depressing the individual initiative for the individual must, even in group work, in the last analysis have the vision. The reports are of value not only for the information of the group but as a permanent record which can be turned to in future times for a record of progress.

In our laboratories, we have devised a system of outside consultants, each a specialist in his own field, who visit our laboratories at periodic times. Some come every two weeks,

some come when we request them and some monthly. In all there have been 26 of these consultants attend our laboratories in the last year. The reports of the workers are available for these consultants so that, when a consultant comes in to discuss any particular project, the report may be first put into his hands and his mind becomes oriented to the work whereon his visit is of immediate value on account of his advance preparation. In one such case, a visit by one of our advisory committee and consultants, Doctor Hugh Stott Taylor of Princeton, we were actually saved a year and a half of work. These consultants come to us usually with a very small honorarium or none at all and I would like to take this opportunity of thanking them for the generosity with which they have shared their special knowledge with us.

The reports are of value in stimulating the birth of research ideas and of correlating the work within the laboratories. Amongst other things, it prevents duplication and often past reports can be studied to show how much has been done on any particular phase and whether it is advisable to continue. One of the most difficult matters of research Directorship is the decision as to what project shall be followed because once committed to a project it usually takes about 3 years before it is wound up or dropped. It is a wise Director who knows when to drop the project and these reports are of great value in getting advice from the consultants as to the merits and advance of the experimentation whether it should be continued or cut off.

The Biochemical Research Foundation coöperates with a number of others which are not biological laboratories but have spheres of interest in chemistry and physics and which lend their knowledge of these phases for the application to the problems of life.

Chief of these is our sister institute, the Bartol Research Foundation for Physics of the Franklin Institute. We have coöperated with them for nine years during which time their director, Dr. W. F. G. Swann, has been a member of our Executive Committee. We are indebted during these years to the Bartol Foundation for the advantages of their glass blower and machine shop for the production of many pieces of apparatus which otherwise would not have been available for us.

At the present time, we are coöperating with the Bartol Foundation in the building of a Cyclotron for the production of artificially induced radio-active substances. It is possible, by means of this enormous piece of apparatus (the magnet alone weighs 80 tons), to impart to elements radio-active force greater than any yet known. For example, it will be possible to produce radio-active sodium with thirteen million γ-ray intensity compared to about the one million γ-ray intensity of naturally occurring radium. The half-life of the radio-active sodium is fifteen hours compared to the half-life of three and one-half days of radon seeds. Numerous other elements have been given this radio-active property by means of the Cyclotron, each with its different quality of intensity and length of half-life.

This opens up a large field of study of neutron bombardment in the biological area and the study of neutron bombardment is yet in its infancy. It is a new force as important as X-rays and radium and the ramifications of its effects will require special and exact study.

The huge Cyclotron will require a year in the making and will not be ready until next Autumn. In the meantime while the construction of the great apparatus is going on, we are preparing a group of our workers who will be prepared with ideas and experience to attack these artificial radio-active problems from the biological and biochemical end. We have some advantage in this as we have been for years working on the biological mechanism of X-ray and radium radiation. It is of equal importance to have a trained group ready to study the biological effects as it is to have the Cyclotron to produce the radio-active substances.

Radiation effects on cells and disease are not the only uses of the artificial radio-active substances. It is possible by introducing artificial radio-active substances into animals to trace by Geiger Counters and other means the course of the radio-active substance in the body and the avenues of excretion. It gives each radio-active molecule a red flag so that it may be followed anywhere it goes in the body. Krogh has done this with radio-active potassium and it can be done with sulphur, carbon, sodium and other elements. This offers a new method and interesting possibilities of study. So that the radio-activity itself is not the only thing which interests us.

In the meantime, the Bartol Research Foundation will have the Cyclotron available for the production and study of Isotopes, a field which intrigues the physicists so much at the present time. So that this is an example of correlation in effort to the mutual advantage of two sister Foundations.

Another very interesting outside venture that we have in conjunction with the Experimental Station of the du Pont Company is the use of the Svedberg Ultracentrifuge.

This enormous centrifuge which is the only one of its kind in this country, and in fact there is only one other outside of Sweden and that is in London, can produce the force of 250,000 times gravity and has a speed of about 60,000 r.p.m. It is possible by means of this centrifuge to study molecular weights and other qualities of substances. It is for this reason very interesting in biological fields to which it has only very recently been applied. We are using this through the kindness of the du Pont Company in the study of proteins and other substances in the blood of diseased people. Professor Svedberg during his last visit here told of some recent applications of this enormous piece of apparatus to the study of biochemical problems. In jaundice, for example, medical men have long divided it into the hematogenous and biliary types of jaundice. It was believed that the porphyrins were combined with one type. Professor Svedberg finds that in all cases of jaundice the porphyrin was combined with the serum albumin and that all jaundice was of one and the same chemical type. So was settled in a day or two, by means of this great new force, a question which had been debated by medical men for generations.

In the coloring matter of the blood, it is of great interest to note that although the molecular weight of such coloring matter is the same, it, in different species, breaks up into different patterns. The hemocyanine, the coloring matter of the blood of crustacea, is found to be species specific. From the Ultracentrifuge analysis of hemocyanine it is possible to tell the species from which the blood originated. This opens a vision in regard to the possibility in this field, and it may be that the hemoglobin in the blood, although of the same molecular weight in each disease, may break up into different patterns also. This is also under study at the present time. We

are also studying the question as to whether the antibodies which are produced in immunization against infection are real chemical substances or whether they are merely adsorbed upon the serum globulin and other proteins. It may be different for different diseases and one step towards the production of a universal immunity is to find out what different chemical combinations exist in immunity. It seems as if this were the only possible piece of apparatus which would make the preliminary study possible.

One interesting new phase in research which has really occurred within the last few years is the use of huge and elaborate pieces of apparatus to give very accurate information not otherwise obtainable upon often very minute amounts of substances. The Cyclotron and the Svedberg Ultracentrifuge are two huge pieces of apparatus; each actually requires a small building to house it. The weight of each must be more than 100 tons. The manipulation of each requires not only skill, but actual experience of a considerable number of months and even years in its use to produce the exact results which it alone can give. This is indeed a romantic chapter in the recent study of research and is only made available by funds enough to plunge into experiment upon such an elaborate scale for each probably costs in the neighborhood of $40,000. While this is a large sum to devote to a piece of apparatus, actually the information obtained is of such accuracy and such value as to be fundamental and unique. Apparatus alone will not do the job because it must be in the hands of skilled people and in regard to these special large machines the skill required often takes a long time to acquire.

This laboratory has followed the fashion of a number of other research laboratories and indeed universities in considering that it is proper and even desirable to take out patents for biochemical substances which are to be used medicinally.

There are a number of reasons why this is advisable. First of all research is a luxury, the flowering of a civilization as art flourished in the 15th century in Italy. It depends for its maintenance upon the excess over necessity. Under the present tax burdens, which no doubt will be continued, large fortunes will probably be destroyed and probably no more large fortunes created. Taxation will become so onerous and

burdensome that there is no longer any excess for the maintenance even for such a productive and re-paying affair as research. One example of this is the recent will of Jesse Isador Strauss, a man with a large fortune. He had left about a million to scientific and charitable purposes, but before his death, with the advent of new taxation, thought this would be such a serious and onerous burden upon his heirs that he revoked all these bequests in a codicil.

Research must either depend upon its own earnings or upon government maintenance such as exists in Russia. This is one reason why we take out patents. As an example of the possibilities the Wisconsin Alumni Research Foundation, starting with no invested capital but only a patent application belonging to one of the university professors, has in 10 years enlarged the research of the University by nearly $700,000 and provided an endowment of $125,000 a year for the needs of research. This was done without harming anyone.

The second reason for patents is, that if the material is to be used in medicine, it must be in the hands of the medical profession and that must be done through the large commercial firms. None of these will handle such a thing unless it is either patented or a secret, because if it is not patented every fly-by-night drug house will have a modification, a copy or a substitute so detracting from the pureness and quality of material as to render it unfit for human use. One example is insulin, the patent of which is held by the University of Toronto and its manufacture is given out by license. This insures the purity and quality of a substance which must be injected into the human body and I am sure that no one who is compelled to use insulin grudges the small royalty which insures the purity of the substance which must be injected.

Each of these reasons seems to me sufficient to make it reasonable that patents should be obtained upon such substances that are of use and that the profit should go for the furtherance of research as it does with us and not for personal profit. Many universities in this country now follow this practice.

One criticism of the laboratories which are allowed to take out patents is that they will be secretive and that other scientists will not be shown the work that is in progress or given

aid from these laboratories. In a considerable experience with the industrial laboratories I have found them much more open and generous in their information as to going work than the university laboratories. One reason is that they are more sure of themselves. There is more correlation between the people, they are in general more coöperative. The university teacher believes that his value is determined by the amount of prestige which he can obtain, so that he is apt to be jealously secretive even in his own sphere. A number of years ago, I thought that it would be a grand idea to correlate all the research upon cancer then in existence in order to prevent undue duplication and that each would get the advantage of the other workers. But I found that university men, who made up the workers, were very jealous of their plans and results, as they considered their advancement within the university to be dependent upon their reputation as gained by publication and that their results were their own stock in trade. The jealousies and antagonisms of the cancer research workers in this country have delayed the cure of cancer many many years. So that it cannot be stated that laboratories, such as ours, which are allowed to take out patents are any more secretive than the university research workers. In fact, I do believe it would be impossible to be more secretive than the university workers. At least in our laboratory, there has been no alteration in the information which we give out now equally as generously as before we were allowed to take out patents.

In the technique of publication and the survey of scientific results the old established customs still hold and these are no longer suited to the pace and necessity of our time. The production of scientific literature in more than 20 languages in hundreds of magazines and tens of thousands of pamphlets pours over us like a flood. The themes of research work are left largely to chance and thousands of problems are recorded without any logical connection. The way out of this chaos is by organization without the suppression of the creative faculty. The principles of scientific management in industry can be applied to the rationalization of the scientific institute for research activity. In no place is this more valuable than in the library itself. We have indeed made an effort in experi-

mentation toward this end in the care of our literature. We have collected most of the needed scientific books and journals in a research library so that our workers very rarely need to go to outside libraries for references. The unique gem, however, is our collection of 16,244 reprints upon subjects which are pertinent to our work and these are indexed, cross indexed and so made available to workers. When an experimental fact gets into a book it is usually out of date. If it can be obtained in the reprint form after publication in a journal it is available in a small form and more helpful in its particular subject.

It is our effort to maintain the interest of the workers in the collection of these reprints. We offer a semi-annual Library prize for the person in the Foundation who has done the most toward building up the library. The people themselves very soon learn the value of this collection of reprints and realize that to maintain it they must do their best for the collection which in my opinion is the most valuable single piece of apparatus to exist in our laboratory.

When any new reprint comes on any piece of work which is pertinent to any particular project, the worker's attention is immediately directed to it in the most helpful way, in fact we consider this part of the general education and development.

In addition to this, we have a special Cancer Library, called the Frederick L. Hoffman Library for Cancer which has resulted from the collection of cancer literature given to us by Dr. Hoffman, famous statistician, upon his retirement from the Prudential Insurance Company. It is being extended and added to as a library which shall be available to all cancer workers and contain as much literature on cancer as is possible to obtain.

In addition, we ask the workers from time to time to make a resumé of special subjects in which we are interested which shall be placed in manuscript in our files, although not for publication yet for the information of the whole group. This is not only informative but formative to the mind and knowledge of the person who does it. In general, our library activities are not only to make a depository for information but to use the library and library facilities as a real educational tool.

In an organization such as ours, which is median between the university laboratory and the industrial laboratory with-

out, I hope, the defects of either and with the merits of both, what is the function of directorship? What part should the director play?

Ideally the director should be an intermediate between the executive type and the intellectual type—where the division should take place who can tell. The intellectual never wants to make up his mind and when he does it is usually in a hurry; the executive type is prone to make up his mind even in advance of the facts because he believes that indecision of aims is sometimes worse than even a wrong decision.

Certainly in the organization of this research, up to now, the director has been of the nature of a general manager.

Still if he is wise, the director will keep in touch with the greater part of the research staff and will not leave personnel problems to other people. Men working in laboratories are very independent people and of a very critical type of mind, extremely impatient of bureaucracy. They are individualists who are being organized as kindly and sympathetically as possible but so as not to interfere with their originality and genius. In management, the plan should be the means and not the end.

So in our laboratories, we are a coöperative group, yet made up of individuals with individual effort and individual rewards. Someone must be the spear head, but that is merely the expression of the great forces behind the leader. The kingdom of a director is in the minds of his people and he can go no farther than he can develop those minds. Distribution of effort makes tasks easy.

So in this humanitarian effort, I bespeak your kindly feelings toward our people who are making a valiant effort for the benefit of mankind. I ask your good wishes for our research and, most where it is needed, I ask your prayers that directorship shall be wise and good.

And so now I am grateful to you for listening to this story of the creation of a research foundation.

Testing Friction Tapes and Rubber Tapes.—H. W. S. YOURY. (*Instruments*, Vol. 9, No. 12.) The Bell Telephone system uses friction and rubber tape widely and certain specification requirements are framed primarily to control the handling qualities of both friction and rubber tapes. These requirements cover such properties as tensile strength, elongation, and tackiness. Other requirements intended chiefly as criteria of serviceability in the telephone plant, are those limiting adhesion. To determine adhesion, a strip of tape is wound on a mandrel under a specified tension, produced by a weight hung from the end of the strip. After the tape is fully wound up, it is held under winding pressure for a specified time and then the winding weight is replaced by a lighter one giving a load of 4 lbs. per inch of width, and the roll is allowed to unwind under its action. The distance it unwinds in one minute is a measure of adhesion. A different method is used for rubber tape, because when layers are pressed together the surfaces in contact actually fuse together. The Laboratories developed apparatus and method to minimize variations in testing the adhesion of rubber tape. Each of two small cylindrical mandrels cut flat on one side is first wound with four layers of the tape stretched to three times its original length and wound on under the tension of a definite weight. Then the two flattened sides are pressed together under a specified load and for a specified time. Following this they are removed to a tensile testing machine, and the force required to pull them apart is taken as a measure of their fusion. As it is just as important for tapes to have satisfactory characteristics a considerable time after manufacture, the Bell System requires that tapes meet a set of requirements after a specified aging process.

R. H. O.

RADIO-TRANSMISSION OF COINCIDENCE COUNTER COSMIC-RAY MEASUREMENTS IN THE STRATOSPHERE.

BY

THOMAS H. JOHNSON, Ph.D.,

Assistant Director of the Bartol Research Foundation of The Franklin Institute.

BARTOL RESEARCH FOUNDATION
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The development in the technique of measuring cosmic-ray intensities and effects in the stratosphere described herein has been guided by two considerations: first, from the standpoint of the interpretation of the results, unidirectional intensity measurements are superior to those which include rays from all directions. This, together with the fact that Geiger-Mueller coincidence counters are applicable to the measurement of a variety of cosmic-ray effects, has led to the adoption of this type of measuring apparatus in preference to the ionization chamber and electroscope. Second, it was considered important not to be compelled to limit the survey of stratospheric cosmic-ray intensities to those inhabited regions of the earth where instruments sent up in balloons can be recovered, and this led to the method of radio transmission of the data. In view of the results of recent investigations [1] of cosmic-ray intensities in the stratosphere, showing interesting maxima and secondary humps in the intensity vs. depth curve, it is obviously important to have a systematic survey of vertical intensities covering a wide range of latitudes with measurements at frequent intervals, in o der to study the effect of the earth's magnetic field on these features of the cosmic radiation. Similar technique can also be used for studying intensities at any other angle, shower intensities, or asymmetries.

The problem of converting coincidence counter intensity measurements into radio signals is simple, for the electric pulse due to the coincident discharge of the train of counters

[1] W. F. G. Swann, JOUR. FRANK. INST., **222**, 669, 1936. G. Pfotzer, *Zs. für Physik*, **102**, 23; 41, 1936. E. Regener and G. Pfotzer, *Nature*, **136**, 718, 1935. R. A. Millikan, H. V. Neher and S. K. Haynes, *Phys. Rev.*, **50**, 992, 1936.

is an almost ideal type of signal from the standpoint of both the transmitter and receiver. Each count can be transmitted and recorded, and the timing of the counts, for determination of counting rates, can be effected at the receiver. The principal problems of design are associated with the reduction of cost and weight in the adaptation of the usual circuits for the selection and recording of coincidences. Here the supply of high voltage for the operation of the counters is a major item. In the design of the counters and associated circuits, the important considerations are, first, the change in efficiency due to the higher counting rates in the stratosphere

FIG. 1.

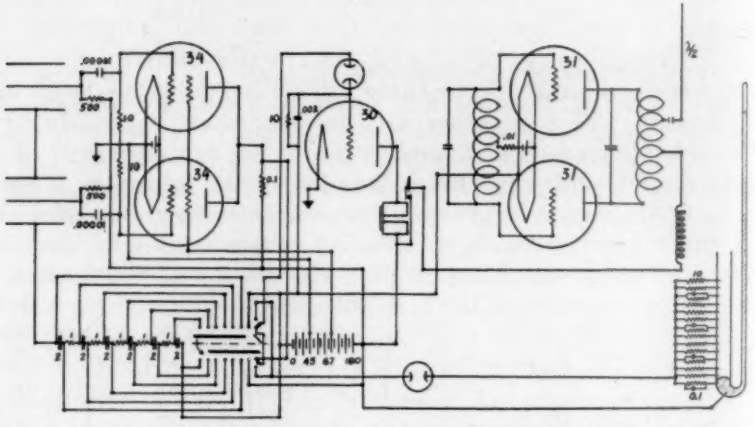


Diagram of electrical connection of the second model cosmic ray radio transmitter. Resistances are given in megohms, capacities in microfarads, and potentials in volts.

and the finite recovery time of a counter, and, second, the change in accidental rate due also to the higher radiation intensities in the stratosphere and the finite resolving time of a circuit (limited by the finite breakdown time of a counter).

A diagram of the electrical connections for the counters and their affiliated circuit, for the high voltage supply, for the barometer signal generator, and for the radio transmitter is given in Fig. 1. Coincidences are selected by means of the usual parallel connection of two No. 34 tubes. Although the characteristics of these tubes are not as good for this purpose as the No. 57 tube, they are quite satisfactory if

operated with a low screen voltage as suggested by Mouzon,[2] and they have the advantage of a low consumption of power by the filament. The large change of plate voltage of the No. 34 tubes caused by the coincident discharge of both counters, is applied through a neon glow lamp to the grid of the No. 30 output tube. This connection is made through a double throw commutator which connects the same grid at regular intervals to the barometer signal generator. The neon tube acts as a selector of coincidences since no charge passes to the grid of the No. 30 tube unless the change in potential across the glow lamp is sufficient to cause it to break down and pulses of this size occur only when the counters discharge coincidentally. In order to avoid "accidental" counts, the initial pulse is limited to a time of the order of the breakdown time of the counter by the use of a low resistance grid leak on the No. 34 tubes. Thus the pulse applied to the grid of the No. 30 tube through the glow lamp is of the order of 10^{-3} seconds and it must be prolonged if it is to operate the relay keying device. This is accomplished by the use of a high resistance grid leak and additional grid capacity in the No. 30 tube. The relay is thus held down for a finite time of the order of a few hundredths of a second, making the signals easily distinguishable from the more rapid pulses due to static of various kinds.

The barometric signal is produced by a neon tube flicker circuit whose frequency is controlled by a resistance and a capacity, both of which are varied according to barometric height by means of a series of regularly spaced taps in a mercurial barometer. The signal consists of a series of regularly spaced pulses whose frequency varies from about three to ten per second, in three or four steps. This variation occurs as the rising column of mercury cuts in additional parallel resistance. After three or four steps of increasing frequency of the barometer pulses, an additional capacity is introduced by the same means and the frequency is again reduced to the starting point. By keeping record of the number of changes in the frequency, it is thus possible to determine from the original calibration what the pressure is

[2] J. G. Mouzon, *Rev. Sci. Inst.*, **7**, 467, 1936. Type 1B4 tubes now replace the 34's.

at any time. In order to avoid oscillation of the mercury column with the swinging of the gondola, a capillary constriction is made in the glass tube.

The transmitter consists of two No. 31 tubes in push pull with tuned plate and tuned grid circuits. In order to stabilize the frequency against changes in temperature and humidity, a large ratio of capacity to inductance is used in the grid circuit, whereas in the plate circuit a larger coil and smaller condenser insure that the circuit will oscillate even though some slight change in tuning takes place. The half wave antenna is attached through a small condenser to the plate coil at a suitable distance from the center. This point is determined as that for which the loading is not enough to throw the circuit out of oscillation but enough to give a satisfactory signal strength. In practice it is found that with an input of six watts in the plate circuit of the transmitter (33 ma., 180 volts) one watt can be radiated (antenna current 120 ma., assumed radiation resistance of half wave doublet 75 ohms). The frequency which has been used in the present work is 41 mc.

As a source of B voltage for transmitter and counter circuit a Burgess X type battery of 180 volts has been used. Filaments are heated by dry cells of suitable capacity. The high voltage for operation of counters is obtained by a condenser multiplying device having the advantages of low cost and light weight over a high voltage battery. This consists of a number of condensers connected permanently in series through one megohm resistors but with taps for charging in parallel at regular intervals. These intervals are made to coincide with the transmission of the barometer signal so that no unnecessary time is lost from the cosmic ray recording. By connecting the high resistances from the counters to the positive end of the B battery the voltage on the counters is equal to one more than the number of condensers times the B voltage. The charging is done by a rotating pair of contact bars which simultaneously connects together taps from corresponding sides of each condenser with taps from the B battery. At the same time a cam attached to the same rotor throws the signal commutator from the cosmic ray detecting system over to the barometer. In order to avoid corona dis-

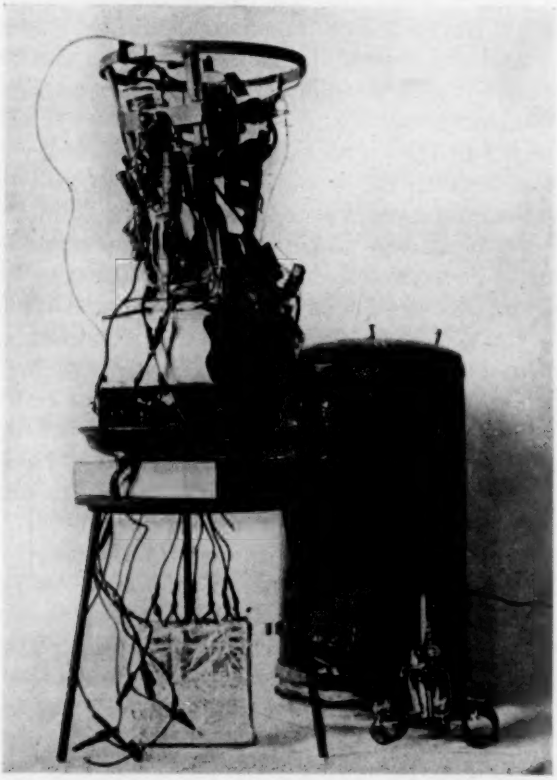
charge from the exposed condenser taps at the reduced pressure of the stratosphere, the switching is done under oil. Paper condensers of light construction with two microfarads capacity have a sufficiently low conductivity if they are kept cool by exposure to the external air. The fluctuation of the high voltage is of the order of 20 volts when charged once a minute. The batteries and other parts of the apparatus are warmed by heat from the sun according to the technique described by Regener and associates. Since the mercurial barometer and the cosmic ray detecting apparatus are insensitive to changes in temperature, no attempt is made to transmit thermometric data.

The nature of the corrections due to inefficiency and accidentals which must be avoided or applied to coincidence counter data taken under conditions of variable radiation intensity is well known and has been discussed at length by G. Pfotzer. These considerations constitute the important limitations on the design of the counters and their affiliated circuits. The accidental counting rate of a train of n counters is proportional to the coincidence rate of $n - 1$ of the counters multiplied by the individual counting rate of one counter. In the case of two counters the accidental rate is proportional to the square of the individual counting rate. The factor of proportionality in each case is twice the resolving time of the circuit determined by the grid resistance of the No. 34 tubes but limited by the breakdown time of the counter. The efficiency of a coincident train is given by Exp $(-nN\sigma)$, where n is the number of counters in the train, N is the individual counting rate and σ is the recovery time of a counter determined by the capacity of the anode system and the stabilizing resistance. The latter is determined by the degree of stability required and the characteristics of the counter. Accidental counts can be reduced by increasing the number of counters in the coincidence train to three, as has been done by Swann, Locher, and Danforth, and by Pfotzer, but in this case the correction for efficiency becomes of increasing importance. This circumstance was met by the above investigators with the breaking up of each counter into a group of small counters each with its own stabilizing resistor. Whether the triple coincidence is superior to the double coincidence

arrangement depends largely upon the characteristics of the individual counter and the degree to which one is willing to sacrifice simplicity and lightness for accuracy. A fuller discussion of this question is reserved for a later publication.

Photographs of two models of the transmitting system are given in Figs. 2 and 3. In the former the entire apparatus

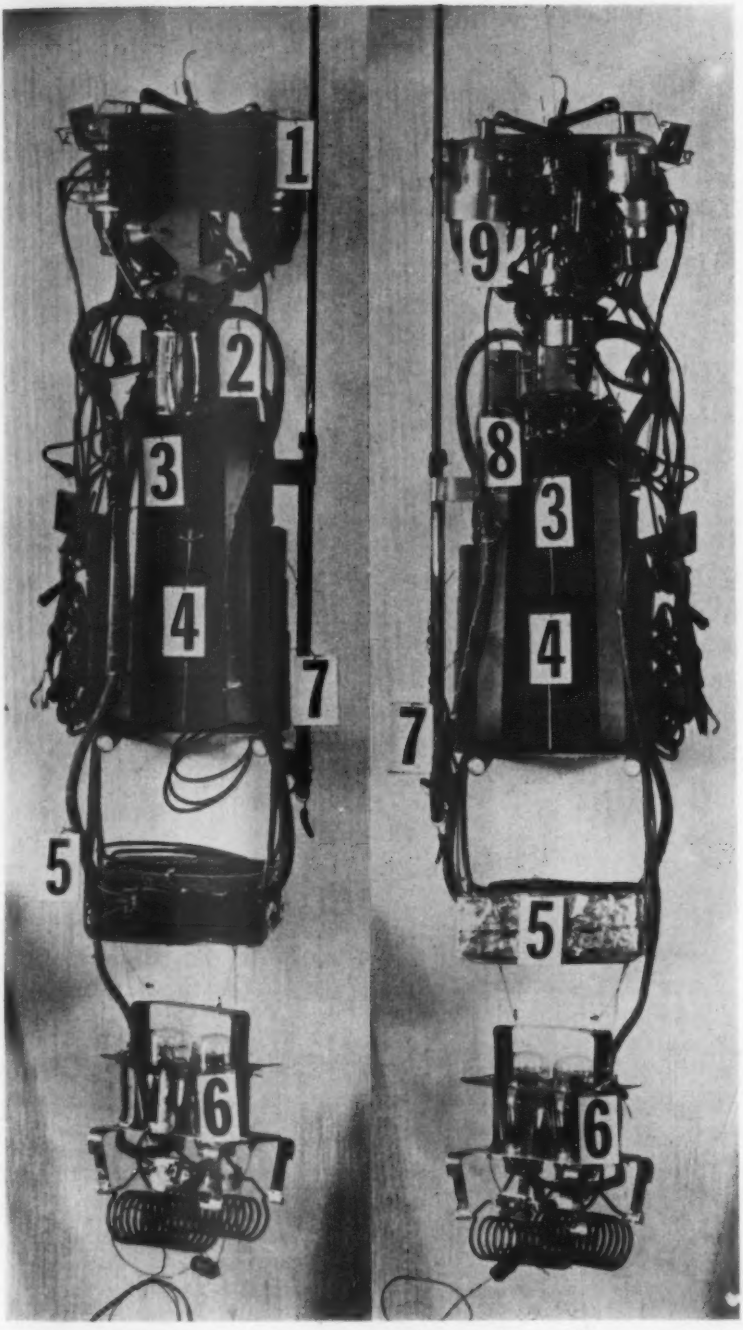
FIG. 2.



First model cosmic ray radio transmitter showing the pressure sealed can used for avoiding corona.

was enclosed in a sealed can at atmospheric pressure for the avoidance of corona from the high voltage leads. The high voltage condensers themselves were swung from outside the can for the cooling effect of the external air and the radio transmitter was swung still farther below in order to avoid

FIG. 3.



Front and rear views of the second model cosmic ray radio transmitter. (1) Coincidence counters, (2) oil cup containing contact points, (3) A batteries, (4) B battery, (5) high voltage condensers, (6) radio transmitter, (7) barometer, (8) relay key connecting to the transmitter, (9) cosmic ray counter circuit.

pick up of the high frequency on the counter circuit. This apparatus weighed 14 lbs. The apparatus in Fig. 3 is designed to withstand the low stratospheric pressure without such protection. It weighs only 8 lbs. The condensers, shown below the batteries, are exposed to the external air but the apparatus above, including the batteries, and barometer, is enclosed in a hot-house arrangement similar to that described by Regener. In both models power for the operation of the switching contacts is obtained by the slow unwinding of a spool upon which is wound a silk gut fiber. This fiber suspends the entire weight of the apparatus from the balloons and sufficient power is obtained by allowing the apparatus to drop away from the balloon at the rate of about two meters per hour. The rate of unwinding is controlled by a simple escapement taken from an inexpensive alarm clock.

The signals are received at the point from which the balloon is released. For this purpose a simple super-regenerative receiver has ample sensitivity and a wide reception band enabling it to use energy from the rather wide transmitted band characteristic of the simple transmitter used. The limit of strength of signal which can be satisfactorily received is determined under ordinary circumstances by the background noise level produced in the 41 mc. band principally by automobile ignition, trolley cars, railroads and other electrical machinery. This type of interference usually consists of pulses of short duration and can be distinguished from the signals from the balloon by the longer duration of the latter. However, more satisfactory results can be realized by locating the receiving station in unpopulated regions. Atmospherics on fair days are of negligible intensity in this band and with man-made interference eliminated, the full sensitivity of the receiver can be utilized. Since reception in the 41 mc. band is limited to something of the order of twice the optical path it is advantageous to locate the receiver on the top of a mountain. Remarkably good reception has been obtained from the summit of Mt. Washington, N. H., which is sufficiently far from settlements and highways to eliminate man-made interference and its height gives an appreciable extension of the horizon. After nearly two hours, when the balloon must

have been 100 miles or more away, signals were received with no appreciable diminution of intensity. It is customary to record the signals both manually, from head-phone reception, and automatically, on a moving film oscillograph. For the automatic recording, the output of the super-regenerative receiver is rectified on a diode detector circuit and then amplified and filtered to eliminate the superaudio frequency introduced by the receiver. The resulting pulse is of the type which can be easily recorded with a low frequency oscillograph mirror.

FIG. 4.

Balloons inflated at the start of a flight. The cosmic ray transmitter hangs in the foreground.

On the recent flights 350 gram balloons made by Dewey and Almy [3] have been used. On these flights the apparatus weighed about 14 pounds and three balloons filled with hydrogen at their maximum expansion of 14 feet in diameter were sufficient to carry the apparatus to a barometric pressure of 35 mm.

The results of one of the Mt. Washington flights made in the fall of 1936 is shown in Fig. 4. The circles indicate the total number of cosmic ray coincidence counts recorded in

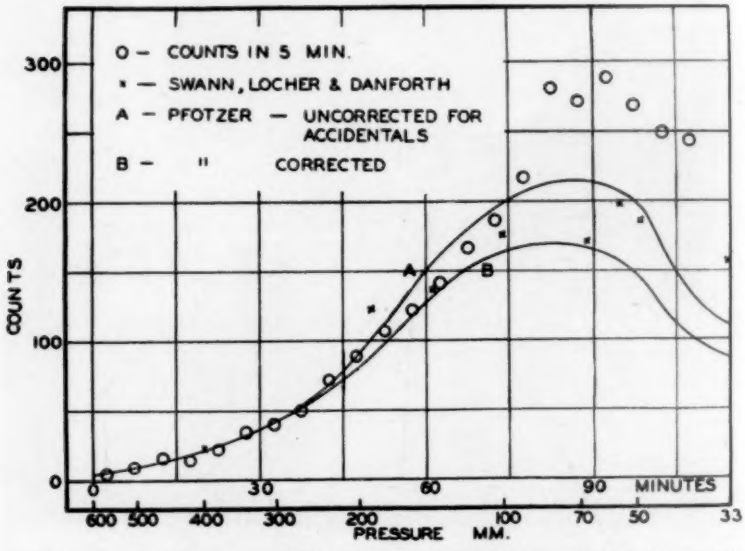
[3] Dewey and Almy Chemical Co., Cambridge B, Mass.

five-minute intervals. These have been plotted against a linear time scale, since there was a failure of the barometric signal on this particular flight. However, the initial lift of each balloon was known and the rising velocity can be determined from the equation

$$v^2 = \text{Lift}/K \cdot 25\pi D^2\rho, \tag{1}$$

where the lift is given in dynes, D the diameter in cms., ρ the density of air and K is a constant having the value 0.32

FIG. 5.



Cosmic ray intensity *vs.* barometric height measured by radio on flight from the summit of Mt. Washington, N. H. The circles plotted to the indicated scale are numbers of coincidences in five-minute intervals. Crosses (x) are results obtained by Swann, Locher and Danforth on the Stratosphere flight of the National Geographic Society and the Army Air Corps, adjusted to correspond with the circles at 400 mm. Curve *A* represents Pfotzer's results uncorrected for accidentals and Curve *B* is the same with corrections.

for spherical balloons. In an isothermal atmosphere the barometric pressure expressed in atmospheres varies with the time according to

$$p = (1 - At)^6, \tag{2}$$

in which A is a function of known constants, and the corrections due to variations of temperature are not severe. Although this method of determining the barometric pressure is

open to serious objection it has been used in order to form a basis for a comparison of the present results with those of other observers. The pressure scale calculated from (2) is introduced along the axis of abscissæ and the corresponding data obtained by Pfotzer and by Swann, Locher, and Danforth are indicated. The upper curve of Pfotzer is uncorrected for accidentals. No means are at hand for correcting the present results for efficiency and accidentals, although it is realized that the principal correction is due to the latter. This will tend to lower the counting rates at the highest elevations, bringing them into better agreement with those of Pfotzer and Swann, Locher, and Danforth. On the other hand, it is to be noted that Mt. Washington is nearer to the north magnetic pole than the point in southern Germany where Pfotzer's flights were made, and for this reason a higher intensity than was observed by Pfotzer could reasonably be expected. The present results, however, are not presented with the view of giving new information on cosmic ray intensity but rather as an indication of the development of the radio balloon technique [4] for the making of further measurements in latitudes as yet unexplored.

CELLOPHANE BALLOON TECHNIQUE.

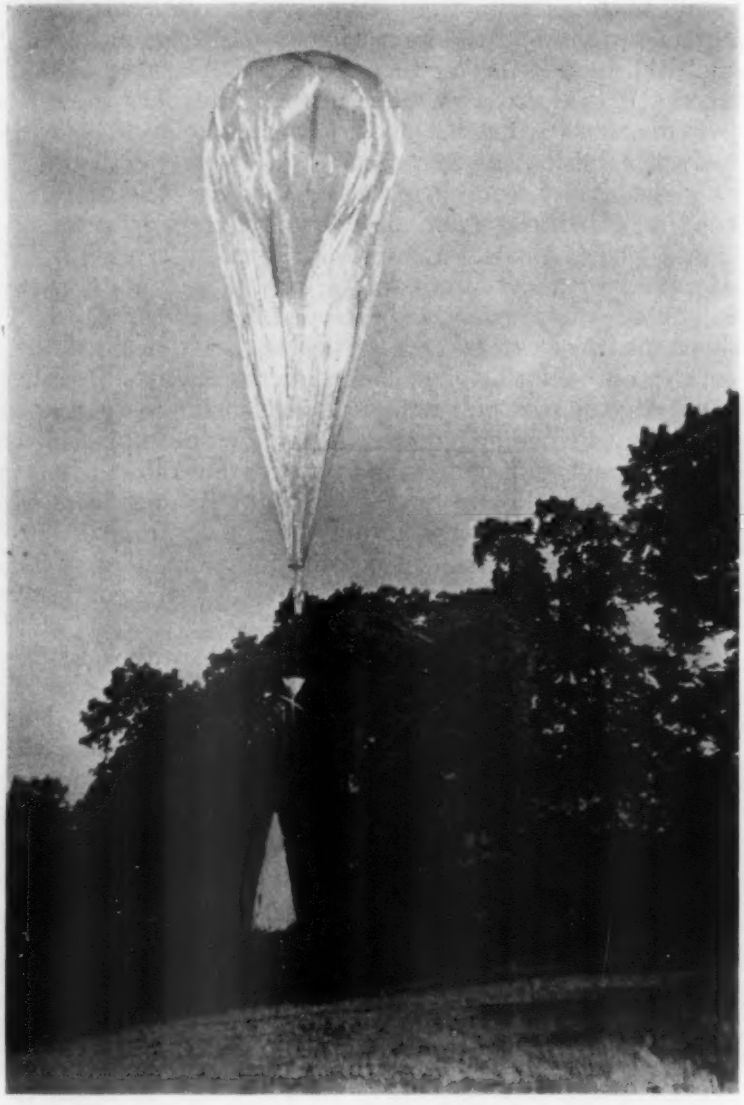
Practically all previous workers have used latex balloons for carrying light weight recording instruments into the stratosphere. For the cosmic ray radio transmitter, three or four balloons of the type made by Dewey and Almy with 350 grams weight are required to rise to a pressure of 35 mm. Because of their moderate cost and their ease of handling at the start, balloons of this type are undoubtedly superior to other types, although it is possible that for heavier instruments or for work requiring continued observations at one level balloons of a rigid fabric may prove of value. As a matter of record, therefore, the development made in the technique of manufacturing and handling balloons of cellophane will be described. This development has been made in cooperation with Dr. Jean F. Piccard.

[4] A method of transmitting by radio the cosmic ray intensities measured by an electroscope has recently been reported by R. L. Doan, *Rev. Sci. Inst.*, **7**, 400, 1936. See also the article in this issue by C. D. Keen.

FIG. 6.

A cellophane balloon shortly after the start of the inflation.

FIG. 7.



The same balloon at the moment of release. Sand is still streaming from the ballast bag and the wind cup valve is in the open position. The balloon is being retained by a string.

Cellophane balloons designed to carry four kilograms of useful load to a barometric height of 30 mm. were five meters in diameter and had the form of a sphere surmounting a 60° cone, whose apex was at the load ring. The bag was constructed of sixteen segments cemented together along the meridians by "Scotch Cellulose Tape," one inch in width. This was applied along the lapped edges by a roller device and it was possible for one man to cement an entire balloon in about eight hours. Plain cellophane, tinted or clear, and waterproof cellophane were used with equal satisfaction. The end of the segments terminated in a load ring twelve inches in diameter of either wood or Dow Metal about which the cellophane was wrapped once and cemented. Just above the load ring on the inside of the balloon was cemented an appendix which projected below the load ring in the form of a ten-inch cylinder three or four feet long. For the inflation this was cemented to a funnel made by cutting off the bottom from a glass bottle and during the flight it hung below the balloon and was sucked flat together, preventing air from entering. After the balloon became fully expanded at high elevations, this appendix opened and allowed hydrogen to escape from below.

If A is the surface area of the balloon, w the weight per unit area, W_0 the load, other than the weight of the balloon fabric, V the volume of the balloon and ρ_{air} and ρ_H the densities of air and hydrogen at a pressure of one atmosphere, then if the balloon is at the same temperature as the surrounding atmosphere, a condition which will be very nearly satisfied in the case of transparent cellophane, the hydrostatic equation gives the ceiling pressure in atmospheres as

$$p = (Aw + W_0)/(\rho_{air} - \rho_H)V.$$

No. 300 cellophane has a surface density of 33 grams per square meter. The volume of the balloon of the above shape is $3/16\pi D^3$ and its area is $9/8\pi D^2$. Taking 1.2 kg. per cubic meter as the difference in density of air and hydrogen, the above equation reduces to

$$p = (W_0 + 0.115D^2)/0.71D^3, \qquad (4)$$

where D, the equatorial diameter, is expressible in meters,

W_0 in kilograms and p in atmospheres. For $D = 5$ meters and $W_0 = 4$ kilograms, the ceiling is .078 atmosphere.

In order to counteract the effect of small leaks, if they existed, and to facilitate the launching, an automatic ballast release was attached just below the load ring. This consisted of a conical cloth bag filled with sand which could run out through a valve controlled by a wind cup. For rising velocities in excess of a predetermined value V_0 this valve was closed, but when the rising velocity fell below V_0 the valve opened and sand was released until the rising velocity had increased to V_0. The wind cup consisted of a small angled cone of cellophane attached to a ring of wire and suspended below the valve arm by a string. For this type of wind cup the conditions are approximately satisfied for the validity of Bernoulli's equation and the force against the cup is given by

$$F = A\rho V^2/2g \text{ grams}, \tag{5}$$

where A is the area of the cup in square centimeters, p the density of the air in grams per cc. at the elevation of the balloon, V the velocity in cms. per sec. and g is 980 cms. per sec.^{2}. The torque due to the force on the wind cup at the minimum rising velocity V_0 was counterbalanced by a lead weight, so that the valve swung from open to closed when this velocity was exceeded, and in the opposite direction when the velocity fell below V_0. The valve was practically frictionless and consisted of a flat sheet of metal which swung a few millimeters below the end of the outlet tube. The sand piling up on this sheet shut off the stream completely without the necessity of a tight joint.

At the launching, the procedure was to fill the sand bag until the balloon was just in equilibrium without the load. The balloon would then rise until it began to pull on the apparatus which hung at some distance below. The sand then continued to run out until finally the load was just lifted. The balloon was then retained by a string attached to the hook of a spring balance. At the instant that the balance read an amount sufficient to give the balloon the desired initial rising velocity, depending upon location and ground wind, the string was released. The action of the

valve thereafter regulated the rising velocity. Ground tests for several minutes before the start on two ascensions failed to show evidence for leaks, but as a precaution the balloons were inflated to carry ten pounds of sand at the desired rising velocity. In the absence of leaks, this would discharge at the ceiling.

On two flights with balloons of this type, the remnants of the balloon and instruments were found approximately thirty miles away, and the indication was that the balloons had torn at about the elevation corresponding to full inflation. It is probable that the appendix had failed to open as expected, due to an unforeseen adhesion.

The developments described have been made with the aid of a grant from the Carnegie Institution of Washington whose support is gratefully acknowledged. Dr. D. N. Read is responsible for valuable suggestions in the design of the instruments, and Mr. A. A. McKenzie has rendered important assistance in all branches of the work. Materials for the cellophane balloons were contributed by the Dupont Cellophane Company. Acknowledgment is also made of the extensive coöperation of The Mt. Washington Club during the flights from the summit.

HIGH ALTITUDE TEST OF RADIO-EQUIPPED COSMIC RAY METER.

BY

C. D. KEEN, M.E.,

Ryerson Physical Laboratory, University of Chicago.

ABSTRACT.

A high altitude cosmic-ray meter, of the type proposed by Benade,[4] has been built and flown. The ionization current in an unshielded argon-filled chamber moves the mirror of a Dershem electrometer. When the reflected light beam falls on a photoelectric cell, the electrometer is discharged and the radio signal is modulated. A pressure device also modulates the signal when certain altitudes are reached. A small quantity of radioactive material introducing a small fixed ionization makes possible convenient measurement of cosmic-ray ionization varying through a large ratio. On April 14, 1936, a balloon flight was made from Shreveport, Louisiana. The instrument and batteries weighed 41 pounds, and were raised by three 8-foot balloons to an altitude of 52,000 feet. During the rapid ascent the swaying of the gondola affected the electrometer mirror, and the cosmic-ray signals were irregular. More satisfactory data were obtained on the slower descent. At 78 mm. of mercury an intensity of 288 standard ions was measured. This preliminary curve is somewhat steeper than that obtained by Millikan and Bowen [7] at about the same latitude. The test has shown that in principle the method is feasible, but that changes in the construction of the electrometer are necessary before wholly satisfactory results can be obtained.

INTRODUCTION.

In order to gain a more complete understanding of cosmic radiation, it is necessary to learn how this radiation varies from place to place on the earth's surface and from sea level to the greatest altitudes which can be reached. Much work has been done in this direction, particularly during the last decade. To study the altitude effect, airplane flights carrying self-registering apparatus have been made at several localities,[1] the maximum height reported being 29,000 feet. Much

[1] R. A. Millikan and R. M. Otis, *Phys. Rev.*, **27**, 645, 1926. K. Buetnner, *Zs. f. Geophys.*, **3**, 170 and 236, 1927. J. Clay, *Kon. Ak. Wet.*, Amsterdam, **36**, 1265, 1927. Bowen, Millikan and Neher, *Phys. Rev.*, **44**, 246, 1933. Mott, Smith and Howell, *Phys. Rev.*, **44**, 4, 1933. G. A. Suckstorff, *Zs. f. Geophys.*, **10**, 95, 1934. Clay and Van Alphen, *Physica*, **2**, 183, 1935. S. N. Vernoff, *Phys. Rev.*, **46**, 822, 1934. Millikan, Neher and Korff, *Phys. Rev.*, **49**, 871, 1936.

greater altitudes (60–72,000 feet) have recently been reached by manned balloon flights [2] but these have necessarily been made at mid-latitudes on the Northern hemisphere. Their cost and the personal hazards involved make them unsuited for an extensive research program. Unmanned balloons, equipped with self-registering cosmic ray apparatus, have been flown to 90,000 feet.[3] In this method of stratosphere exploration the success of the experiment depends on the finding and return of the instruments to the experimenter. The apparatus required is not heavy and small balloons are sufficient to carry the equipment to great heights.

A fourth procedure is to have the measuring apparatus transmit its readings by radio to the observer on the ground, while the flight is in progress. Using this technique, the finding and return of the apparatus are not requisite and the method is thus available at any location. On the other hand the instrumentation is more complicated than for self-registering apparatus and the greater weight sets additional problems. This procedure was initiated by Prof. J. M. Benade,[4] while visiting at the University of Chicago.

In the balloon experiment here described this radio technique has been used. The object was to obtain a working test of a method of measuring total intensity in the stratosphere. The test has shown that in principle the method is feasible. There are, however, important details which require development before wholly satisfactory results can thus be obtained. Since many others are now engaged upon similar experiments, it may be of interest to describe in some detail the results of this trial.

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[2] A. Gockel, *Phys. Zs.*, **11**, 280, 1910. A. Gockel, *Phys. Zs.*, **12**, 595, 1911. V. F. Hess, *Wien. Ber.* (II A), **121**, 2001, 1912. Kolhoerster, *Prob. Kosm. Phys.*, Hamburg, 1924. A. Gockel, *Phys. Zs.*, **16**, 345, 1915. A. Piccard and M. Cosyns, *Comptes Rendus*, **195**, 604, 1932. A. H. Compton and R. J. Stephenson, *Phys. Rev.*, **45**, 441, 1934. W. F. G. Swann and G. L. Locher, *Phys. Rev.*, **47**, 326, 1935. A. W. Stevens, *Natl. Geogr. Mag.*, **69**, 693, 1936.

[3] J. S. Bowen and R. A. Millikan, *Phys. Rev.*, **43**, 695, 1933. Regener, *Naturwiss.*, **20**, 695, 1932. J. Clay, *Physica*, **1**, 363, 1934. Regener and Auer, *Phys. Zs.*, **35**, 784, 1934. Regener and Pfotzer, *Phys. Zs.*, **35**, 779, 1934. Regener and Pfotzer, *Nature*, **136**, 718, 1935.

[4] J. M. Benade and R. L. Doan, *Phys. Rev.*, **47**, 198, 1935.

APPARATUS AND EQUIPMENT.

The complete system required for this experiment consists of the cosmic ray meter and gondola, auxiliary meter, balloons and the receiving apparatus. These will be described in the order named.

The Cosmic Ray Meter and Gondola.

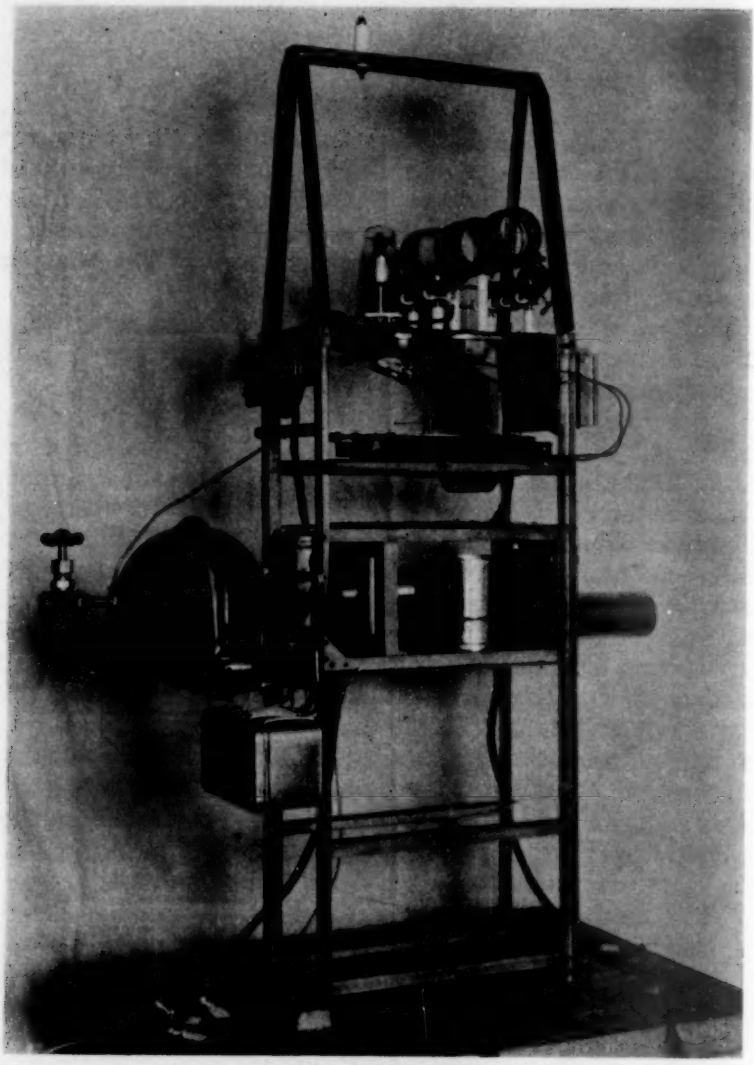
The principle of the cosmic ray meter may be briefly stated as follows: the ionization current in an unshielded argon-filled chamber moves the mirror of an electrometer. When the reflected light beam falls on a photocell, the electrometer is discharged and the radio signal is modulated. A barometric device also modulates the signal.

Figures 1 and 2 show a photograph and a detailed drawing of the instrument, while Fig. 3 gives its circuit diagram with values of resistors, condensers, etc. The $6'' \times 12'' \times 36''$ frame is made of Dow metal. Above is the 70 meter transmitter A. B is the pressure device. Under the pressure device is placed the ionization chamber C, connected through the shielding can D to a Cenco-Dershem electrometer E. The beam from the light source F is reflected by the mirror of the electrometer, when this is in the proper position, through a narrow slot in the shielding can G, on to a photoelectric cell. When the central electrode N is grounded, the lightspot will be a certain distance from the slot. As the ionization current charges the electrometer the light spot moves towards the slot. When it falls through the slot on the photocell, the current set up is amplified in the usual manner by the vacuum tube contained in H. The change in its plate current energizes a magnetic key in D, grounding the central electrode, which moves the lightspot back to its original position. At the same time the transmitter signal is modulated.

The time which elapses between two groundings of the central electrode is inversely proportional to the ionization current and therefore a measure of it. When the instrument is aloft, the radio signals therefore give information as to the intensity of the ionization current in the chamber. Shield can K contains the voltage supply for the electrometer. $L_{1,2}$ are the platforms for the power supply.

The ionization chamber is a steel sphere of 6″ diameter,

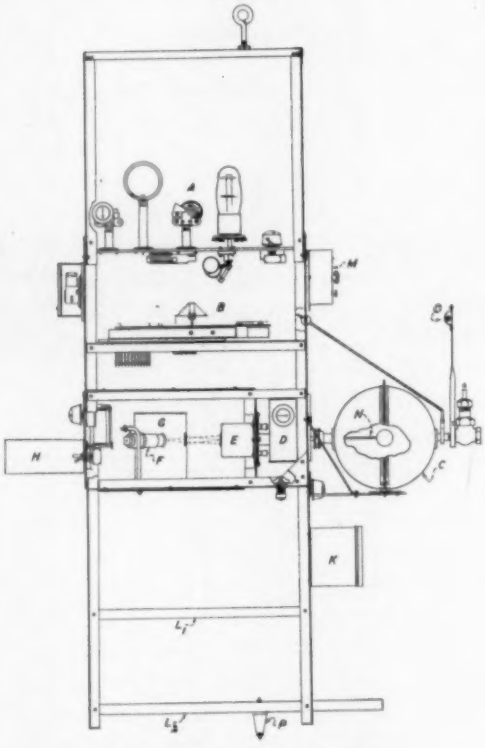
FIG. 1.



The instrument.

wall thickness 0.020″, filled with very pure argon at eight to ten atmospheres pressure. The supporting frame is so arranged that the chamber can be mounted or dismounted in a few minutes, which is of importance in the procedure followed. A battery of dry cells maintains the shell at + 135

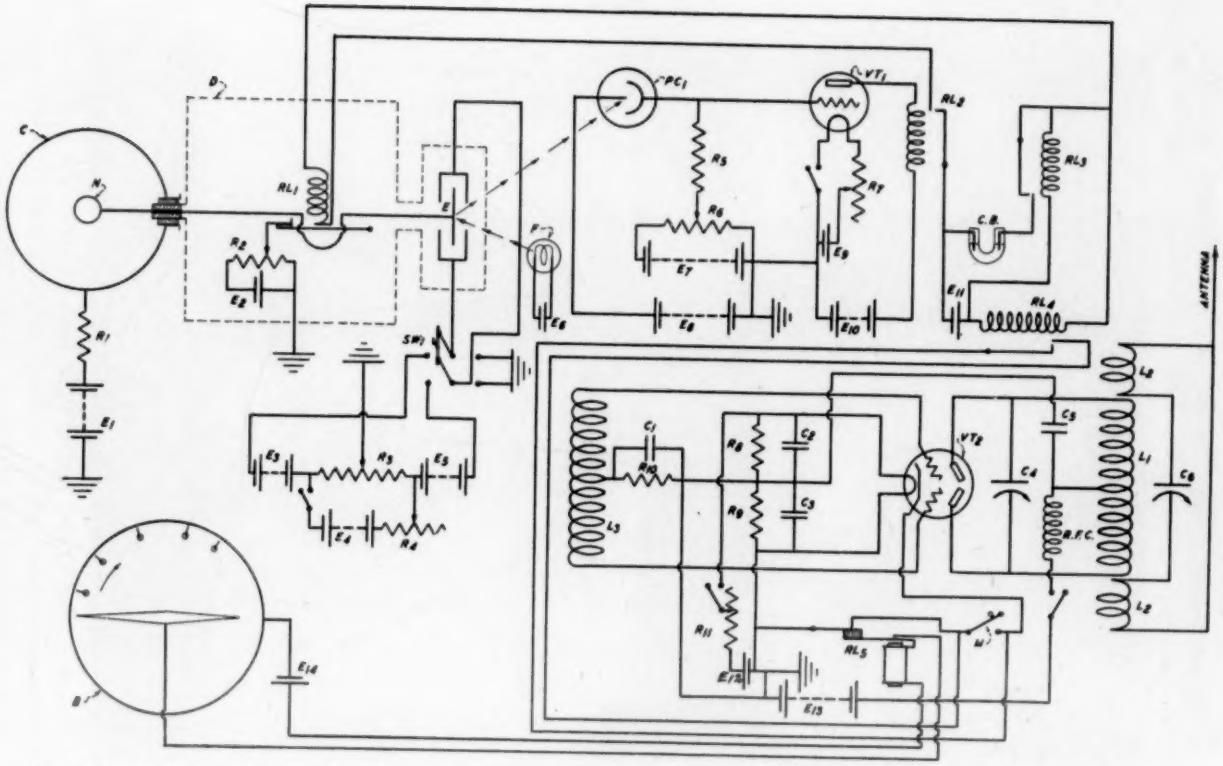
FIG. 2.



Detailed drawing of the instrument.

volts potential, through a 250,000 ohm resistor. The central electrode *N* carries at its end a 1″ hollow brass sphere to produce a more uniform field in the chamber. Where *N* passes through the shell it is separated from it by a grounded guard ring. The shell, guard ring and central electrode are insulated from each other by thin tapered amber bushings, cemented with beeswax. The central electrode passes through

FIG. 3



Circuit diagram of the instrument. R_1, 250,000 ohm; R_2, 3 megohm; R_3R_4, 50,000 ohm; R_5, 50 megohm; R_6, 1 megohm; R_7R_{11}, 30 ohm; R_8R_9, 200 ohm; R_{10}, 5000 ohm; E_1E_{10}, 135 V.; E_2, 1.5 V.; E_3E_5, 36 V.; E_4, 24 V.; $E_6E_9E_{11}E_{14}$, 3 V.; E_7, 22.5 V.; E_8, 90 V.; E_{12}, 6 V.; E_{13}, 202.5 V.; Rh, Headphone coil; Rl_2, Western Electric B 1003; Rl_3, Western Electric B 46; Rl_4, Buzzer coil; Rl_5, Buzzer; C_1, 100 $\mu\mu$F; C_2C_3, 0.01 μF; C_4C_5, 250 $\mu\mu$F; C_6, 0.002 μF; RFC, Radio frequency choke; Vh, No. 19 vacuum tube; Vt_2, No. 6A6 vacuum tube; PC_1, Visitron 72-A; L_1, 13 turns 1/8" c.t., space between turns 1/16", Diameter 2"; L_2, 7 turns 1/8" c.t., space between turns 1/16", Diameter 2"; L_3, 54 turns No. 22 d.c.c. on 1 1/8" O.D. bakelite tubing; C. B., Delayed circuit breaker. M — Clock work key.

the shield *D* and is connected to the needle terminal of the electrometer. The grounding key is a fine platinum wire spiral, which moves only 1/16″. The small motion and the lengthened contact time make for a more reliable discharge.

By means of a small 1.5 volt battery and potentiometer the grounding key imparts a negative potential to the central electrode equal to half of the voltage change on the electrometer needle. The leakage current over the insulation is thus about half the time from guard ring to central electrode and flows in opposite direction during the remainder of a cycle, practically eliminating errors which might arise through changing leakage conditions.

The electrometer (*E* of Figs. 1, 2 and 3), developed by Dr. E. Dershem of the University of Chicago, is similar to the Lindemann instrument, but has a movable mirror which gives it a somewhat greater period.

The metal capsule *O*, clamped to the ionization chamber, contains a small amount of radioactive material, which adds a constant background to the radiations to be measured. By so adjusting its quantity and distance from the chamber that the background is one-fourth of the maximum intensity expected, the experimental data, instead of being nearly absent on the lower part of the curve and crowded at the top, will be more uniformly distributed. In addition, the electrometer can be used at lower sensitivity.

The shield *G* can be turned in its base, providing for an easy adjustment of the position of the slot. The photoelectric cell is mounted in a socket, which is filled with paraffin to prevent leakage between the terminals over the glass of the cell. The 50 megohm resistor is mounted in sealing wax in the base of the shield *G* and is paraffin coated.

The change in the plate current of the tube caused by the photoelectric current changing the gridbias energizes relay Rl_2 (Fig. 3). The closing of its controlled circuit energizes relays Rl_1, Rl_3 and Rl_4. Rl_1 discharges the electrometer, the lightspot moves away from the slot in shield *G*, the photoelectric current ceases and Rl_2 opens its controlled circuit. Relay Rl_4, when closed, short circuits the transmitter key, but since a single click would be the only signal, giving evidence of the fact that the electrometer has been discharged, another

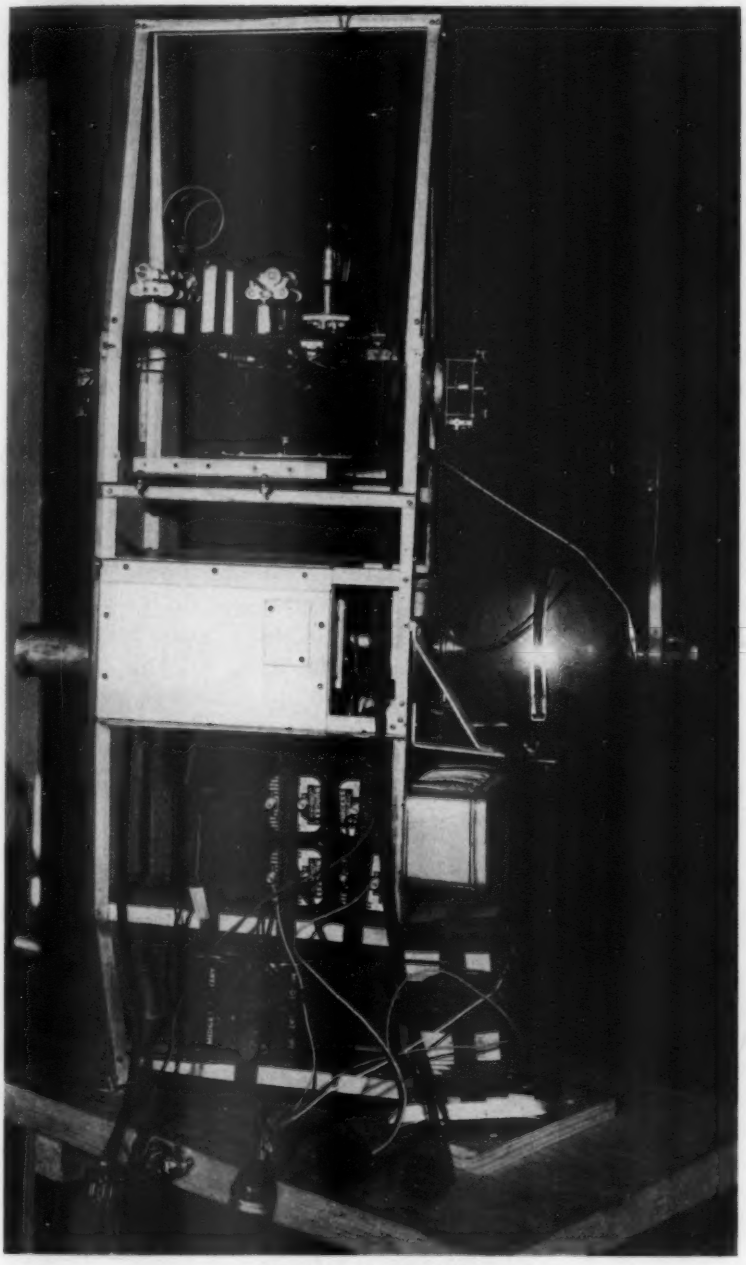
arrangement is necessary. When relay Rl_3 closes, current from E_{11} flows through the delayed circuit breaker C.B., an ingenious device, developed by Prof. J. M. Benade. It is a small U-shaped glass vessel; the electrode on one side is a spiral of fine tungsten wire, which dips in the mercury which half fills the vessel, the other terminal is a heavier tungsten wire, which likewise dips in the mercury in the other leg. The current, heating the tungsten spiral, expands the air above the mercury, which forces the mercury down until the contact is broken and the circuit opened. As soon as the plate current of the No. 19 tube drops to zero, Rl_2 opens, but the current from E_{11} passes now through the circuit breaker and holds relays Rl_3 and Rl_4 closed, until the circuit breaker opens the circuit.

The expansion of the evacuated sylphon of the pressure device B (Figs. 1, 2 and 3) is communicated by gears to the needle, which is insulated from the circular plate beneath it. The needle carries at its end a bent free swinging platinum wire, which touches the platinum contacts on the circumference of the disc, as the pressure changes. When a contact is made, circuit E_{14} is closed, which energizes buzzer Rl_5, which is a part of the keying device and modulates the transmitter signal.

The transmitter is essentially a T.N.T. circuit.[5] The key M placed in the cathode lead of the transmitter tube is a clockwork, the keying being done by a light platinum wire, moving back and forth with the balance wheel. The signal, unmodified by the pressure or cosmic ray device, is a series of dashes numbering 120 per minute and of $\frac{1}{4}$ second duration. When Rl_4 is held closed, the key M is short circuited and the signal becomes continuous for four seconds. When Rl_5 is energized by the pressure device, the interrupted or the continuous signal is modulated with a frequency of 50 cycles per second, giving a coarse note which can easily be recognized, both in the written and audible reception. The transmitter used in the flight had about 2 watts in the antenna and gave a signal of strength 4.5 in a ground test at a distance of 71 miles. The insulator P (Fig. 2) serves to bring the antenna wire through the gondola cover.

[5] The Radio Amateur Handbook, 1936, 126.

FIG. 4.



Instrument after the flight.

The power supply for the instrument (except the electrometer) consists of 4 Burgess "Little Six" cells, 1.5 volts each, 7 General Dry Batteries "V-30-AA," 45 volts each, and 3 General Dry Batteries "V-30-PW," 45 volts each, weighing altogether 17 pounds. Figure 4 shows how the batteries are placed on the platforms L_1 and L_2, L_2 being extended beyond the frame of the instrument, so that it can be balanced, when suspended from the hook at the top.

The V-30-PW's furnish voltage for the ionization chamber. At the proper taps on the V-30-AA's voltages are taken off for the photoelectric cell, "C" bias of the 19 tube and for the plates of the 19 and 6A6 tubes. The four 1.5 volt batteries in series furnish the filament current for the transmitter tube, while two of them in series supply the current for the light source. The other two in series supply the filament current for the 19 tube, the circuit breaker CB and buzzer Rl_5.

The steady current drain on the 1.5 volt batteries amounts to 1.75 amp., with a maximum drain of 2.85 amp. Two test runs were made, with fresh batteries, under flight conditions, and it was found that there is power available for a 2.5 hour flight. When the current through the circuit breaker falls too low, it does not function and the relay Rl_4 fails to release.

To preserve all available power for the flight, two 5-wire cables are used for the leads to all parts of the instrument. These cables are of sufficient length to protrude a few inches through the gondola cover, each having a plug at the end, properly marked for identification (see Fig. 4). Two similar cables, also with plugs, come outside the gondola from the power supply. A few hours prior to the take-off, when the gondola has been put in place, the instrument, adjusted, is left operating on auxiliary batteries, which have two cables and plugs similar to those of the power-supply of the instrument. When ready for the take-off, the instrument is switched from the auxiliary to its own power, the operation taking less than one minute.

The antenna bus wire comes down from the antenna coil alongside the instrument and is brought out through the gondola base by means of the insulator P. The 120 ft. antenna has a small iron hook at the end to prevent too much swaying.

To protect the instrument from stratosphere temperatures

the gondola (Fig. 7) was built, in the manner developed by Prof. E. Regener. The upper portion of the Dow metal frame is covered with metallation (aluminum foil on heavy paper), while the lower part of the covering is celluloid. The bottom of the gondola is covered with heavy black paper. A black paper cylinder is attached to the lower part of the instrument, there being a space between the bottom of the cylinder and the gondola floor. The sun's radiation captured in the space between the celluloid cover and the black paper cylinder, will tend to set up circulation inside the gondola. A test, made on a freezing day, showed that the hot house effect amounted to a temperature difference of 45° F.

The total weight of the instrument, power-supply and gondola was 42 pounds 9.5 ounces.

Auxiliary Meter.

Since the instrument does not lend itself readily to a measurement of its constants, an auxiliary meter was built. This consists of the ionization chamber to be used in the flight, a connecting shield can with electromagnetic grounding key and a second electrometer, similar in construction and sensitivity to the one in the cosmic ray meter. Determination of voltage sensitivity, capacity, leakage, ionization chamber's own radiation and the total radiation, are measured using this auxiliary meter.

A few hours before the take-off, the ionization chamber, with the radium capsule in place, is moved from the auxiliary meter to the instrument. The total ionization current being known, the only observation to be made on the instrument is the time between two consecutive groundings of the electrometer. This time can be adjusted by changing the sensitivity of the Dershem electrometer, the position of the slot in shield can *G*, the bias on the discharge key and the sensitivity of the photocell amplifying circuit.

Since the instrument's signal time, as adjusted, corresponds to a known ionization current, the current corresponding to any other interval between two signals can be readily computed.

Balloons.

The balloons, three in number, were furnished by the Sterling Rubber Company of Guelph, Ontario, Canada, and were guaranteed to expand to at least 15 ft. diameter before exploding. They were made of only slightly vulcanized rubber, weighed between 7 and 8 lbs. each, and at the bottom had a 1″ nozzle for inflation. On their equator they had eight heavy rubber loops, to be tied to the cords. By suspending the instrument and gondola by eight cords and arranging the balloons "in tandem" (one above the other), leaving ample space for expansion, tying each cord to one loop of each balloon, the strain on the balloons themselves is reduced to a minimum, the pull at each loop not being more than about 2 lbs.

By letting three and one-half foot balloons of known lifting power ascend at a greater speed than was to be used in the flight an empirical expression was found, for the relation between air drag (or net lifting power), diameter of the balloon and rate of ascent, of the following form:

$$R = 0.000145\,V^2D^2.$$

Here R is the air drag or required net lifting power in lbs., V is the velocity in ft./sec., and D is the diameter in feet. By net lifting power is understood the load which would have to be added to make the balloon float. This expression should be applicable for spherical balloons between 3.5 and 8 ft. diameter, when the product of the diameter in feet and the velocity in ft./sec. lies between 75 and 125. The coefficient 0.000145 contains amongst other things the density of the air through which the balloon moves. Assuming that the expression is valid for larger balloons moving through air of less pressure, as in ascending, then if the lifting power remains constant the rate of ascent should increase, because the density varies inversely with the cube of the diameter of the balloon, while D in the expression is only squared. In fact, V^2 should be proportional to the diameter of the ascending balloon.

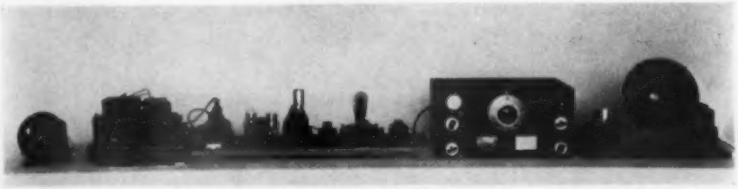
It is further suspected that the form factor contained in the coefficient decreases for larger balloons. This increase

in rate of ascent has been observed by Regener [6] in his flights in 1934, when the speed was more than doubled at 70,000 ft. A similar increase was noted during the present balloon flight.

Receiving Apparatus.

Figure 5 shows the apparatus used for the reception of the signals. A 47 vacuum tube is coupled inductively to the

FIG. 5.



Receiving apparatus.
From left to right: tape winder, Western Union Telegraph Co. "Undulator," full wave rectifier and No. 47 vacuum tube, National Company H. R. O. short wave receiver, loud speaker and power pack.

output circuit of the short wave receiver and the changes in its plate current are inductively transferred to the recording device, which is a Western Union Telegraph Company undulator. As it was feared that atmospherics or other interference might blur the written record, the receiver was also equipped with a loud speaker, which proved to be of the greatest value during the experiment.

PREPARATION FOR THE FLIGHT.

Permission was obtained from Mr. H. L. Mitchell, Commissioner of the Department of Streets and Parks of Shreveport, La., to make the flight from the city's Municipal Airport. In the beginning of the month of April, 1936, a 28 ft. × 40 ft. observation tent was erected at the airport to house the receiving apparatus and the other equipment.

On April 11th the instrument radiation was determined with the auxiliary meter, in the salt mine of the Carey Salt Company, near Winnfield, La. The local plus cosmic radiation was measured in the observation tent on the nights of

[6] Regener, International Conference on Physics, 1934. I. Nuclear Physics, 254.

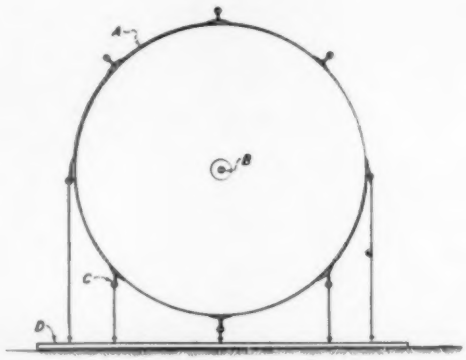
April 12th and April 13th. Inspection of the weather map of April 13th showed absence of pronounced pressure maxima or minima over the southern part of the United States, Shreveport being in a minimum area. Barometric pressure during the week ending April 13th averaged 29.90 inches with maximum fluctuations of 0.2 inch from the average.

On April 13th Lieutenant R. M. Losey, stationed at March Field, Riverside, Calif., who had kindly offered his assistance, advised that for the week beginning April 14th, the best flight conditions would prevail on the morning of April 14th after sunrise. It was decided to attempt the flight at that time.

At 00:30 A.M. of April 14th, after the second set of readings for the local plus cosmic radiation had been made, the capsule with radioactive material was attached to the ionization sphere and the added ionization determined, all on the auxiliary meter. At 1:00 A.M. the ionization chamber, with the capsule in place, was moved from the auxiliary meter to the instrument, and the time between successive electrometer discharges adjusted to an average of 225 seconds. Inflation of the balloons began at 2:30 A.M. They were laid on woolen blankets and inflated with hydrogen, until they almost lifted their own weight. The equatorial loops were then attached by means of hooks and strings to a piece of $2'' \times 4'' \times 10'$ lumber, which served as anchor (see Fig. 6). Since the excess pressure inside the balloons is negligible (not more than 3 cm. of water), the nozzles were closed by inserting small round metal cups, which facilitated the filling and weighing. By placing the wood anchor and balloon on scales the net lifting power can be determined within an ounce without difficulty. The balloons' diameter, after inflation, was about 8 feet, the time for inflating and weighing each balloon being thirty minutes. At 5:00 A.M. the gondola was put over the instrument, which was then left suspended and operating on the auxiliary batteries, and the antenna was attached. Shortly after sunrise the inflated balloons, still attached to their anchors, were brought outside the observation tent and placed thirty feet apart, two men handling one balloon. The cords were tied to the equatorial loops on the balloons and to the instrument and gondola, which had been brought from

the observation tent at the proper time after the change from auxiliary to own power had been made.

FIG. 6.



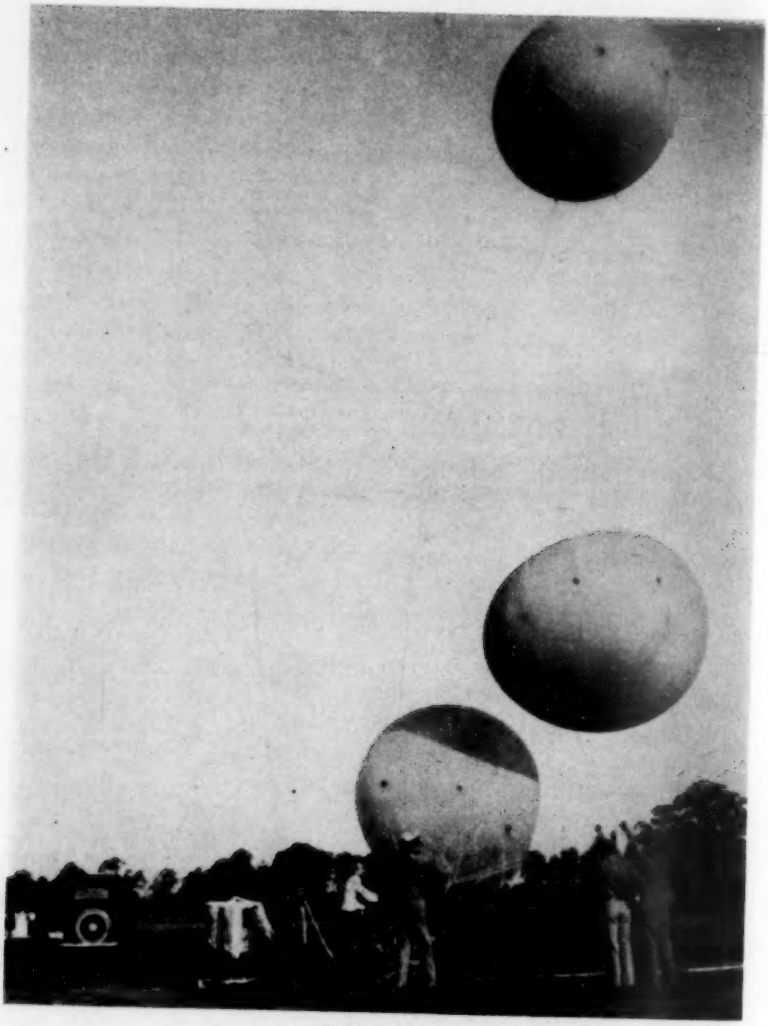
Showing manner in which balloons were handled after inflation.

When ready, the balloons were allowed to rise slowly, one after the other, and finally the instrument released.

THE FLIGHT.

The take-off was at 7:08 A.M. (Fig. 7). The weather conditions were very favorable. The balloons were aloft until 9:36:55 A.M., when they landed three miles north of Arcadia, La., forty-eight miles east of Shreveport. An airplane followed the balloons, flying at 13,000 feet. The position of the balloons was measured by engineers every five minutes from a base line, east of the airport, until 8:25 P.M. The pilot landed at Arcadia, La., emptied two of the balloons, the lower one having exploded at 9:10 A.M., five miles south of Arcadia, La. The apparatus and balloons were moved back to Shreveport the same day. During the entire flight the radio reception was good. The tape record was fair for the beginning and end of the flight, interference blurring the record during the middle part of the flight. The audible record, however, was very good and the signals could be heard plainly at considerable distance from the receiving apparatus. Four observers were used to record the signals and keep the receiving apparatus adjusted.

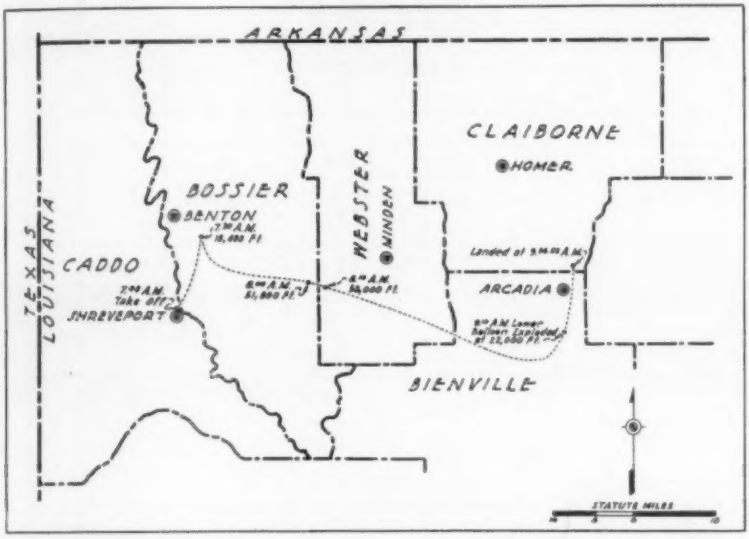
FIG. 7.



The take-off.

From the engineers' data and the position report of the pilot, the path of the balloons can be fairly accurately determined. It is shown in Fig. 8. At 7:30 the balloons were

FIG. 8.



Index map of N.W. Louisiana showing approximate path and altitude of the balloons. The wind up to 20,000 feet was S.S.W., above 20,000 feet it was W.N.W.

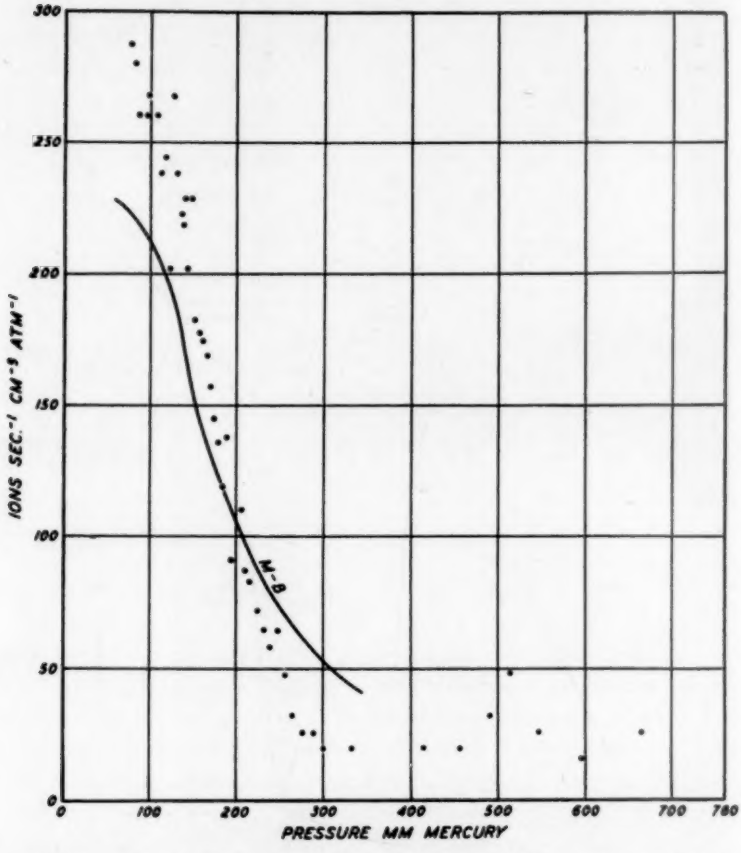
near Benton, La., at an altitude of 18,400 feet. At 8 A.M. they had reached 52,000 feet and were near Minden, La. They then descended rather slowly to 22,000 feet during the following seventy minutes, when they had reached a position south of Arcadia, La., and the lower balloon exploded.

RESULTS.

The 48 cosmic ray signals received during the ascent have not been computed, because the time intervals, although decreasing from 225 seconds at the take-off to 55 seconds at the top of the flight, are too irregular. This irregularity is attributed to the motion of the electrometer mirror, which, through its fine quartz fiber suspension, was too much influenced by the swaying of the gondola. The remaining 49 signals, 42 of which were received during the slow descent to

22,000 feet, have been computed and plotted against pressure in Fig. 9, the last seven corresponding in time to the rapid

FIG. 9.



Ionization plotted against pressure, computed from data received during the flight. The solid line, marked *M–B*, was obtained by Millikan and Bowen in 1932 at Dallas, Texas, 200 miles W. of Shreveport, La.

descent to earth after the explosion of the lower balloon at 9:10 A.M.

The pressure device functioned fairly satisfactorily. Based on the experience of this flight, the belief is stated that a device which gives the existing pressure continuously is preferable over one which only signals the pressure at intervals.

These data are submitted to show what results can be expected from the method, rather than as a measurement, establishing the values of cosmic ray intensities in the high altitudes at Shreveport, La. For comparison the curve obtained by Millikan and Bowen [7] in their Dallas, Texas, flights in 1932, has also been plotted in Fig. 10 (solid line marked *M–B*).

ACKNOWLEDGMENTS.

In conclusion I wish to thank Prof. A. H. Compton and Dr. R. L. Doan for many helpful conversations at the Ryerson Laboratory, University of Chicago, and Mr. M. R. Hebert, of the Air Navigation Division, Department of Commerce, stationed at Shreveport, La., whose knowledge of radio instrumentation and radio communication was of great help in building the apparatus and carrying out the experiment.

[7] Bowen and Millikan, *Phys. Rev.*, **43**, 695, 1933.

This Pipe Goes Places.—(*Power*, Vol. 81, No. 1.) This country's first coal handling system using a traveling pipe line for transporting coal went into operation recently at the Whippany, N. J., plant of Manhattan Rubber Mfg. Division of Raybestos-Manhattan, Inc. This conveyor operates on an entirely new principle. A heavy walled rubber tube, split longitudinally, divides to receive coal from the track hopper, closes, then rises 80 ft. and opens to discharge into a storage silo. Replacing a bucket elevator, the new system handles 9 tons of anthracite rice coal an hour. Capacity is based on the 2-inch internal diameter conveying tube traveling 300 ft. a minute. Mechanical simplicity, cleanliness, quietness and freedom from vibration are notable. Each half of the moving conveyor tube is really an endless belt with a chain embedded in the rubber to give mechanical strength, the chain carrying the load and the rubber acting as a casing for the material. Double tongue-and-groove joints seal when the belts are put together. After the halves are in place, making a tube, the assembly is twisted like a rope, compressing the joints, making a tighter seal and preventing the tube from opening. The loading half of the conveyor is fitted with disc-like partitions or flights which pick up a full load when passing through the loading hopper and prevent slipping and backing on the vertical lift. Loading at the track hopper is made possible by separating and guiding the two halves of the tube around separate sheaves. Coal flows from the hopper into the load belt, which then passes under the sheave around which the belt cover is running, joint side out. This forces the two sections together. In emptying the tube, guide rollers first remove the twist from a section directly over the discharge hopper, leaving the joints vertical. The halves separate, dump the load, pass over separate drive pulleys, and are resealed. Then the twist is restored and the conveyor returns to the loading hopper.

R. H. O.

A CONTRIBUTION TO THE CHEMISTRY OF TURKEY EGGS.

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S., M.D., Ph.D.,

and

PAUL REVERI MIRAGLIA, B.S., M.D.,

Hahnemann Medical College, Philadelphia, Pa.

Previous papers in this series (1, 2) have been devoted to the chemical composition of the eggs of the chicken (*Gallus domesticus*), goose (*Anser anser*) and duck (*Anas erythrorhynchos*). The present paper considers the chemical composition of the eggs of the domestic turkey (*Meleagris gallopavo*).

Eleven turkey eggs were used; the maximum, minimum, and average weight of an individual egg was, respectively, 92.7, 70.1, and 80.5 grams. Separate analyses were made of the whole egg (i.e., edible portion or mixed white and yolk) of 6 eggs, and of the white and the yolk of 5 eggs. The white and the yolk were separated by the procedure described by Hepburn (3) for hen eggs. The whole eggs, the shells, and the yolks were actually weighed. The weight of the edible portion and that of the white were determined by difference. The shells formed 9.88 per cent. by weight of the 11 eggs. In 5 eggs, the white formed 64.26 per cent. of the edible portion, the yolk 35.74 per cent. The analyses were made according to the methods of the Association of Official Agricultural Chemists (4) and included determination of moisture, crude fat (ether extract), crude protein, and ash. Total solids and ether extract were dried in a gas-heated, water-jacketed oven at the boiling point of water. Fat was extracted from the total solids with ethyl ether by means of an electrically heated Knorr apparatus. Ash was obtained by incineration in quartz dishes in a gas-heated muffle furnace. For protein determinations, use was made of the Gunning modification of the Kjeldahl method; and the total nitrogen was multiplied by the factor 6.25. The dextrose content was determined also by the colorimetric method described by Hepburn and St. John (5).

The results are presented in Table I which records also caloric values, calculated on the basis that 1 gram of fat yields 9.3 large or kilogram calories, and 1 gram of protein or of carbohydrate 4.1 such calories.

TABLE I.

Chemical Composition and Caloric Value of Turkey Eggs.

	Whole Egg.	White.	Yolk.
Total solids, per cent	28.64	13.78	51.74
Moisture, per cent	71.36	86.22	48.26
Ether extract, per cent	12.29	0.05	33.35
Crude protein, per cent	12.97	11.38	15.24
Ash, per cent	0.66	0.51	1.29
Dextrose, per cent	0.3629	0.4255	0.2703
Calories per 100 grams:			
Fat	114.3	0.5	310.2
Protein	53.2	46.7	62.5
Carbohydrate	1.5	1.7	1.1
Total	169.0	48.9	373.8

Study was made also of the influence of the solvent upon the yield of lipins (crude fat). Samples of the whole egg were dried, then extracted for 16 hours by means of an electrically heated Knorr apparatus. The solvents used and the per cent. of lipins (calculated on the moist basis) found with each were:

Ethyl ether	12.29
Petroleum ether	14.98
Chloroform	13.70
Carbon tetrachloride	14.79
Benzene	13.44
Carbon disulphide	13.46
Ethyl acetate	13.88

The lowest value was obtained with ethyl ether, the highest with petroleum ether.

The constants of the yolk fat were determined also, using the lipins obtained by extraction of the dried solids of the yolk with petroleum ether in a Soxhlet apparatus. The methods of analysis were those of the Association of Official Agricultural Chemists (4). The iodine number was determined by the Hübl method as described by Lewkowitsch (6), the index of refraction by means of a Spencer refractometer, the total

phosphorus by oxidation with sulphuric acid and potassium nitrate, precipitation as ammonium phosphomolybdate, and final weighing as magnesium pyrophosphate. The values obtained were:

Iodine number (Hübl)	65.8
Acid value	7.7
Saponification number	184.7
Ester value	177.0
Soluble acids (calculated as per cent. of butyric acid)	2.24
Hehner number	85.99
Index of refraction at 40° C.	1.4638
Phosphorus (per cent. P_2O_5)	0.43

SUMMARY.

1. Determination has been made of the chemical composition and caloric value of the edible portion, white, and yolk of turkey eggs, also of the constants of the yolk fat.

2. The per cent. of lipins found in the yolk varied with the solvent used, the lowest value was obtained with ethyl ether, the highest with petroleum ether.

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Research at the Lowest Temperatures.—(*Engineering*, Vol. CXLIII, No. 3704.) In a public lecture delivered before the Institution of Chemical Engineers, Professor F. A. LINDEMANN, M.A., F.R.S. dealt on this subject. After explaining how the conception of the absolute zero, as the temperature at which interchangeable heat motion ceased, although a minimum quivering motion of the molecules still remained, had been reached, he dealt with the methods by which gases had been liquefied and then referred to a new method of cooling substances which, he said, had been introduced during the last few years. This depended upon a curious magnetic effect. In the Clarendon Laboratory to obtain the lowest temperatures by this means, a piece of alum was cooled in liquid helium to a temperature of about 1 deg. abs., a magnetic field then being applied and heat evolved. As, however, the alum was left in thermal contact with the liquid helium, the heat was carried off and the whole system cooled to about 1 deg. abs. The helium gas which made the thermal contact between the alum and the outer bath of liquid helium was then pumped off so as to insulate the alum, as far as possible, from external surroundings. Then, on the removal of the field, the temperature would fall and in this way substances could be cooled below 0.01 deg. absolute. The object in cooling to these low temperatures was to measure the characteristics and properties of substances in this region. One of the phenomena investigated was the fall in the specific heats of solids which led to results exactly in accord with the quantum theory, and actually first caused scientists to realize that the Quantum Rules were absolutely general and not confined to the transfer of radiation to and from matter. With regard to the direct applications of low temperature research in industry the lecturer said he had no doubt that in, say, 15 years time, liquid hydrogen would be just as much an article of commerce as liquid air now is.

R. H. O.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

UNIDIRECTIONAL COSMIC-RAY INTENSITIES AND THEIR VARIATION WITH LATITUDE.*

BY

THOMAS H. JOHNSON.

Geomagnetic cosmic-ray effects are of especial interest because of their bearing upon the problem of the nature of the primary cosmic radiation. As the writer has previously pointed out,[1] the variations of intensity with latitude depend upon the sum of the positive and negative electrically-charged components and the west-east asymmetry depends upon their difference. From measurements of both effects it is possible to determine the intensity of each of the two charged components. The accuracy of the determination depends upon the accuracy of the measurements of the two magnetic effects and upon the accuracy of the assumptions underlying the theory of the effects, from which the energy-limits are determined. If the assumption is made that the Earth's field is that of an eccentric dipole, the theory of Lemaitre and Vallarta [2] may be applied, but on this basis inconsistencies in the estimates of the composition of the primary cosmic radiation arise when the experimental results from different longitudes are considered. Such inconsistencies appear to be greater than can be accounted for by the experimental errors and they lead to the suspicion that local anomalies in the Earth's magnetic field, not specified by the field of the dipole, are having an important influence on the observed geomagnetic cosmic-ray effects. This suspicion constituted one of the reasons for making unidirectional measurements of the cosmic-ray latitude-effect, for it was realized that rays from

* Reprinted from Transactions of the American Geophysical Union, 1936, pages 176–178.

[1] *Phys. Rev.*, **45**, p. 569, 1934, and **48**, p. 287, 1935.

[2] *Phys. Rev.*, **49**, p. 719, 1936, and previous articles referred to therein.

the vertical direction should be more subject to such local effects than those incident from other directions. There was also the need for quantitative measurements of the latitude-effect from particular directions, notably the vertical direction, in terms of the sensitivity of the coincidence-counter train, for with this instrument there is no correction to be made for the absorption of the cosmic rays in a lead shield such as is used in the electroscope-technique and it is with this instrument that asymmetries are measured.

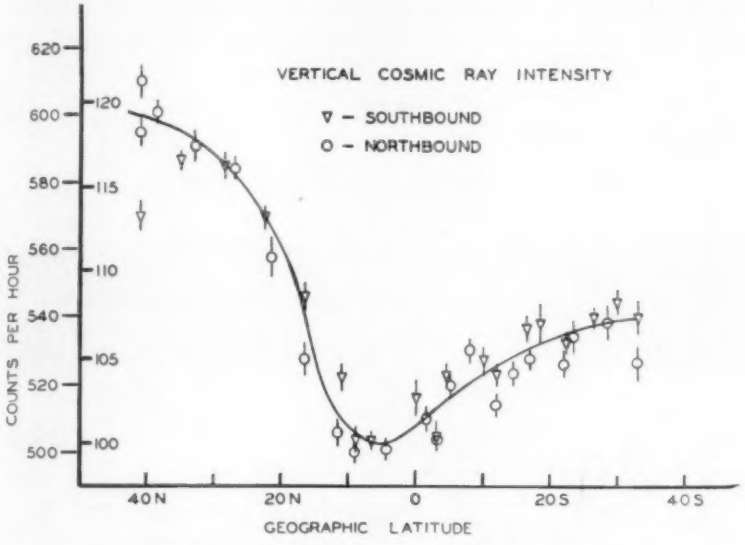
The unidirectional cosmic-ray intensity meter developed by the writer and Dr. Donald N. Read is suitable for mounting on board ship and is capable of making unattended voyages of considerable duration. It embodies eight separate instruments, each giving its own independent record. In December 1935 this instrument completed its first successful voyage on the Grace Line steamship *Santa Barbara* from New York to Valparaiso and return, north and south along the 75th meridian. On this voyage six of the instruments were arranged in duplicate for recording rays from three directions, namely, the vertical and at 45° on either side of the vertical in the plane perpendicular to the meridian. Three of these instruments brought back successful records. The two additional instruments were arranged for recording showers of cosmic rays generated as a result of nuclear encounters in a block of lead. One of these instruments was successful.

The counters were mounted in a sealed box which was swung freely on two mutually perpendicular horizontal axes allowing the apparatus to maintain a fixed direction in space regardless of the pitch and roll of the ship. The coincidences, selected and amplified by suitable vacuum-tube circuits, were transmitted through a flexible cable to a set of recording dials mounted inside of another box. These dials were photographed at regular intervals by an automatically operated camera. The apparatus was powered from the ship's dynamo and regulating devices were used to compensate the fluctuations in voltage.

Figure 1 shows the variation of vertical intensity with latitude. In reducing the results hourly readings have been corrected for barometer and the averages have been taken of the 24 hours from midnight to midnight. This average is

plotted against the noon latitude. The probable errors, represented by the vertical lines, have been calculated from the dispersion of the hourly readings. The agreement between the northward and southward voyages is indicative of the absence of systematic errors due to temperature-variations, aging effects, etc.

FIG. 1.



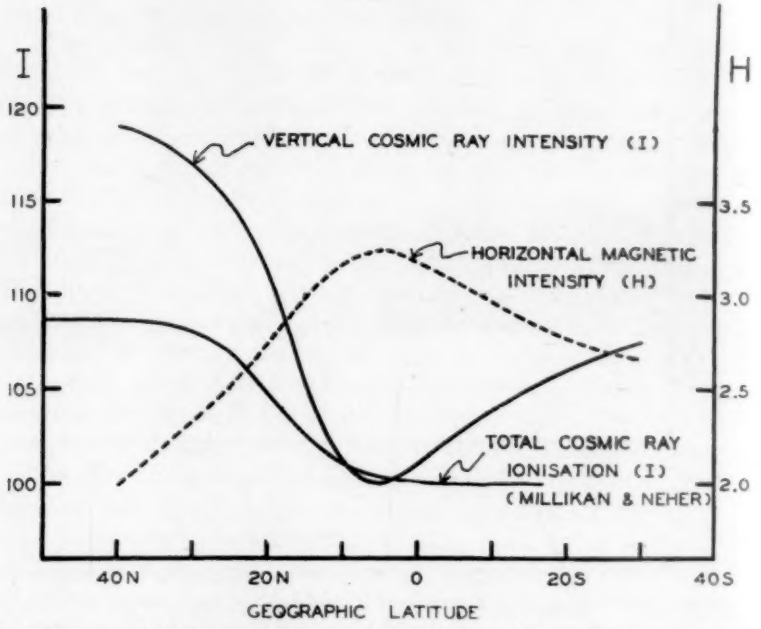
Vertical cosmic-ray intensity versus geographic latitude.

In Fig. 2 the variation of the vertical intensity is compared with that of the total intensity as recorded by one of Millikan and Neher's [3] electroscopes with a 10-cm. lead shield. There are two conspicuous differences. The vertical intensity passes through a sharp minimum at 5° north geographic latitude instead of on the geomagnetic equator at 12° south geographic latitude; and the total variation of the vertical intensity is about 20 per cent. compared with seven or eight per cent. variation in the total intensity. The constant high-latitude value seems not to have been reached at either New York or Valparaiso. Considering the second difference first, a greater latitude-effect was to have been expected for the vertical

[3] *Phys. Rev.*, **47**, p. 205, 1935.

radiation since it was already known that the magnetically deviable component was less penetrating than the average radiation. Rays passing through the atmosphere along the short vertical path would thus be represented in greatest proportion by the soft component. The ratio between the latitude-effects measured by the two techniques is quantitatively consistent with the known values of the absorption-

FIG. 2.



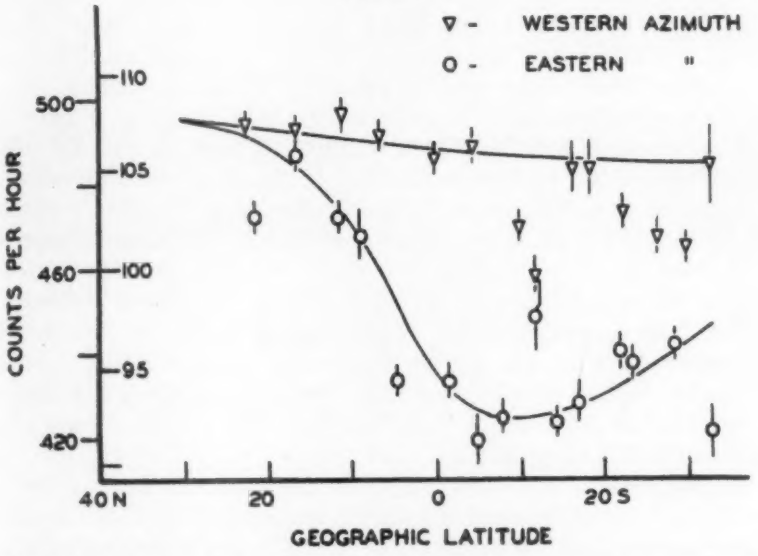
Vertical cosmic-ray intensity, average cosmic radiation, and magnetic horizontal component versus geographic latitude.

coefficients of the average radiation and of the magnetically deviable component. In regard to the position of the minimum of the intensity of vertical radiation, this coincides with the position of maximum horizontal magnetic field plotted along the same course as represented in Fig. 2. This is a striking example of the importance of the local field in determining the energy-limits of the radiation which reaches the Earth's surface from the vertical direction. These rays experience much of their bending during the last few thousand

miles of their trajectories and they have no opportunity to strike an average of the local anomalies. Inclined rays which make up most of the intensity measured by the electroscope have much more of a tendency to spiral around the Earth and back and forth between the Northern and Southern hemispheres. Thus their deflections are more characteristic of the average field of the Earth, represented by the eccentric dipole.

The results obtained with the coincidence-trains pointing at 45° from the vertical are represented in Fig. 3. These

FIG. 3.



Latitude-effects of rays incident at 45° from plane of the meridian in eastern and western azimuths.

results are presented not without some apology, for a slight temperature-effect was found in one of these trains, due to some faulty resistors, and this probably had an effect on the results at the extreme northern end of the voyage. However, the remaining data are probably reliable within the limitations of the relatively high probable errors. The greater latitude-effect in the eastern azimuth, shown by the lower curve, is consistent with the asymmetry previously found at the equator. The magnitude of this asymmetry deduced from

the present values is 14 per cent., which accords with the value 14.5 ± 1.6 per cent.[4] found in 1933 at sea-level in Peru at the same zenith-angle.

The apparent absence of a latitude-effect in the western azimuth is an indication of a phenomenon which deserves considerably more attention. If confirmed by further experiments this will be the first directly observable proof of the absence of sea-level effects from a negative component of the primary radiation. Positive rays of the relatively low energies which become magnetically excluded at this angle at the equator would not be expected to reach sea-level with any appreciable intensity and hence no very great latitude-effect can be attributed to them. The corresponding negative radiation would have two and one-half times the energy and, if such were present in the primary beam, it would be expected to produce a latitude-effect similar to that found for the positives in the eastern azimuth. Perhaps a more important cause of the difference between the eastern and western latitude-effects than the absorption-effect mentioned above is the range of energies which become involved in the band which is excluded from the equator but not from the higher latitudes. At 45° on the western side of the meridian this band includes positive rays in the range from 0.24 to 1.0×10^{10} volts, whereas on the eastern side of the meridian at the same angle the range is 0.26 to 2.5×10^{10} volts. For negative rays the azimuths are reversed.

The results obtained with the shower-counting arrangement are not shown but it may be remarked that these results were concordant with observations made in Pennsylvania and Mexico in 1934.[5] The latitude-effect for the showers is less than that for the vertical radiation and no appreciable change of intensity begins to show until a latitude of less than 20° is reached. The total latitude-effect for the showers is of the order of five per cent. This result has the interpretation that the rays which produce the showers are less affected by the Earth's field than the average radiation. They may be produced by a component of the primary radiation which for a given magnetic rigidity is less penetrating as regards the

[4] *Phys. Rev.*, **45**, p. 569, 1934, and **48**, p. 287, 1935.
[5] *Phys. Rev.*, **47**, p. 318, 1935.

atmosphere than is the case with the average radiation, or it may be that the showers are produced with higher probability by the more energetic radiation.

The results reported here have been obtained under grants from the Carnegie Institution of Washington, to whom acknowledgment is gratefully made. We are also indebted to the Grace Line, Incorporated, for permission to install the apparatus on its ship.

Modern Design and Light Sections Used in San Francisco Street Cars.—(*Iron Age*, Vol. 138, No. 26.) Modernization in design and construction of street cars is exemplified in the new cars built by the Bethlehem Steel Co. for use on the new San Francisco-Oakland Bridge. Bethlehem's Mayari R steel was used for the body, including skirt, sub-floor and equipment supports, substantially reducing the body weight, thus effecting an important saving in the total weight of each unit in addition to that which was saved by elimination of one truck in each unit by articulation. Another reason Mayari R was used in the body construction is its resistance to corrosion and its ability to combat the atmospheric conditions that the trains will encounter in their $8\frac{1}{4}$ mile trip across San Francisco Bay. Aside from unusual construction features, these new cars provide conveniences for passengers that represent a long step forward in passenger transportation over short distances. Heating system maintains constant thermostatically controlled temperature, similar in principle to the air-conditioned heat now employed for residences. The ducts for the system are located between the inner and outer side walls. Electrically operated fans, capable of handling 4000 cu. ft. per min., draw in fresh air through louvers in the side walls and into the car through grilles placed under each seat. Except for the intake louvers and exhaust ventilators in the ceiling, the cars will be sealed. When employed for ventilation only the system will be manually controlled.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

RADIO INSTRUMENTS AND MEASUREMENTS.

Because of continuing demand for Circular C74, Radio Instruments and Measurements, the Bureau has arranged for reprinting of this publication, which has not been available for several years. The new issue is a reprint of the second edition of March 10, 1924, with errata indicated and obsolete appendixes omitted. The subject matter of the publication, although much of it was written 20 years ago, is of current value to radio engineers and students.

Among the subjects treated are the fundamentals of electromagnetism; the principles of alternating currents; graphical methods of solving radio circuit problems; methods of measuring radio-frequency resistance, inductance, capacity, and current; and formulas and data for the calculation of inductance, capacity, resistance, and other quantities.

The Circular has 329 pages. No free stock will be available at the Bureau, but copies can be obtained at 60 cents each from the Superintendent of Documents, Government Printing Office, Washington, D. C.

REFRACTIVITY OF WATER.

The validity with which equations can represent temperature variations in the refractive index of distilled water has been investigated by Leroy W. Tilton and John K. Taylor as a preliminary to the use of such equations in adjusting and interpolating experimental data that are being used as a basis for extensive tables of the refractivity of water. Measurements of index were made at 13 equidistant points between 0° and 60° C. by the method of minimum deviation using a water-jacketed hollow prism mounted in a stirred air bath on the table of a spectrometer.

* Communicated by the Director.

Thiesen's form of density equation

$$(1 - d) = \frac{(t - A)^2}{B} \cdot \frac{t + C}{t + D}$$

was transformed for use in representing refractivities, and the resulting equation was compared with 4- and 6-parameter equations written in the usual manner with powers of t, all adjustments being made by least squares with a precision of a few parts per million. Thiesen's form of equation was further tested by using it to readjust the data on density of water as observed by Chappuis at the International Bureau in 1891 and 1897. The results by these tests which are given in the *Journal of Research* for February (RP971), were examined statistically and it is concluded that this type of equation is superior to a power series in t for representing the refractive index, and also the density, of distilled water.

SULPHIDES IN CEMENT.

Among the minor constituents of certain portland cements are small amounts of sulphides associated with compounds of manganese and iron. These latter compounds prevent the accurate determination of sulphide sulphur by the usual evolution method. A modification of this method has been effected by Harry A. Bright, in which stannous chloride is used during solution of the sample to prevent oxidation of hydrogen sulphide by the higher oxides of manganese and iron. This work is described in the February number of the *Journal of Research* (RP968).

ELASTIC AND PLASTIC PROPERTIES OF CONCRETE.

A number of important investigations have provided information on the elastic and plastic properties of concrete. In order to obtain additional data on these properties, A. U. Theuer has made a series of tests to determine the effect of different temperatures within the range 26 to 123° F. on the elastic and plastic deformation of portland cement concrete when subjected to sustained compressive stress. As described in RP970 (*Journal of Research* for February) tests were

made on concretes of two greatly different strengths and under three widely different conditions of moisture content. The specimens were subjected to sustained compressive stress for periods of 3 days, deformation readings being taken both immediately before and after loading, at intervals during the 3-day period of loading, immediately after unloading, and thereafter at intervals during the 3-day period following unloading. For all tests the stress was held at what was estimated to be 20 per cent. of the strength of the specimens. The plastic and elastic deformations observed in this study are arbitrarily subdivided and termed as follows: The deformation that took place within 0.2 hour after the start of loading is referred to as the elastic deformation, while that part which occurred between 0.2 hour and 72 hours after loading is termed the time deformation; the total deformation that occurred in the 72-hour period of loading minus the total recovery that took place within 72 hours after unloading is referred to as the residual deformation. It was found that for all three moisture conditions, saturated, semidry, and ovendry, the modulus of elasticity decreased with an increase of temperature. When saturated or semidry, both the time and residual deformation increased rapidly with an increase in temperature. In the dry condition, the time deformation was relatively small and constant throughout the temperature range, while the residual deformation decreased slightly with an increase in temperature.

MOISTURE EXPANSION OF CERAMIC WHITEWARE.

During the preparation of a report by R. F. Geller and Ansel S. Creamer on moisture expansion of ceramic whiteware, the question was raised as to what data were available to support the assumption of Schurecht that the difference in total thermal expansion, obtained at 400° C. or at a higher temperature, in the first and second tests of specimens which have had the opportunity of reacting with moisture (either during prolonged storage or in an autoclave), is an indirect measure of expansion caused by the reaction. Since such data were not found in the literature, a brief study was made to obtain them.

The moisture expansion of a number of specimens of ceramic whiteware was measured directly, and also indirectly by means of the interferometer, after autoclaving and after 1 year's storage in a moist atmosphere. Differences in values obtained by the two methods are no greater than differences between duplicate determinations by the direct method. The results, therefore, show that the assumption made by Schurecht is substantially correct.

TESTS OF AUTOMATIC FIRE ALARM SYSTEMS.

At the request of the Bureau of Marine Inspection and Navigation, tests of automatic fire alarm systems and their component parts were begun under the direction of S. H. Ingberg of this Bureau in 1930 to establish bases of requirements for design, materials and performance, and to determine the acceptability of devices submitted for approval under such requirements. By Act of Congress, this type of protection has been required for new passenger, or freight and passenger, vessels since 1916. The results of the tests have also been used in formulation of specifications for equipment and details of installation as required for Government buildings.

The thermosensitive element is the most essential portion of the automatic fire alarm system, since the protection afforded depends largely on its prompt and reliable operation. The general types of automatic fire detecting elements can be divided into two general classes, rate-of-rise elements and fixed-temperature elements, with sub-divisions within each.

Fixed-Temperature Elements.—This type of element actuates the alarm when its temperature reaches a certain degree which for ordinary temperature rises means a considerably higher surrounding air temperature. One of the oldest is the fusible alloy type, such as the soldered link and the strut-type automatic sprinkler head. As adapted to thermostatic elements other than sprinklers, the alloy has been placed in the form of a disc between a metal plate on one side and a perforated insulating plate on the other, fusing of the disc causing the perforations to fill and an electrical contact to be established. This type of thermosensitive

element has also been placed to form the core of a slotted steel sheath insulated from an outer copper sleeve by means of servings of insulating thread. The melted alloy core issues through the slot in the sleeve and makes an electrical contact between it and the copper outer sleeve. The whole assembly is insulated and protected with braid and is generally known as thermostatic wire. In other forms of spot thermostats the fusing of the solder under tension from springs opens or closes electrical circuits.

Recently, there have been developed some hard compounds with sharply defined melting temperatures lower than the standard sprinkler solders, that have been applied in automatic sprinkler heads and, to a limited extent, in thermostats.

The bimetallic thermostat is actuated by the deflection of a bimetallic strip, which causes an electrical contact to be made or broken. In a recent form the strip is inclosed in a glass tube filled with hydrogen, which serves as a protection against corrosion or tampering.

In the mercurial thermostat the contact is made by the mercury column, which rises and contacts wires embedded in the glass and projecting into the capillary. Another thermosensitive element consists of a silica glass bulb filled with a liquid that expands with temperature sufficiently to disrupt the bulb, thus making or breaking an electrical contact. The temperature of operation is adjusted by varying the size of a vapor bubble within the bulb.

Rate-of-Rise Elements.—Among rate-of-rise elements the pneumatic type has perhaps been more widely used than any other. Its operation depends on the expansion from the heat of the fire or air within a vent-compensated system, which deflects diaphragms forming one side of connected air cells, to make an electrical contact instrumental in sounding the alarm. The operating pressure and vent are so adjusted that pressures built up from ordinary temperature changes will not cause false operation of the system. The air volume concerned can be contained in long runs of fine tubing or can be consolidated in clusters of tubing or in bulbs of relatively large volume.

Another rate-of-rise element is of the thermopile type in which an electromotive force is created by a temperature rise between the exposed and protected ends of several thermocouples in series. If the rate of temperature rise is sufficiently slow, the protected and unprotected junctions will be at nearly the same temperature and accordingly no electromotive force sufficient to actuate the alarm will be produced. However, if the rate-of-rise exceeds a certain limit, the temperature difference will create an electromotive force sufficient to operate the relay connected with the alarm.

Other types of rate-of-rise elements depend on the relative expansion of rods of different diameters or on the relative deflection of bimetallic strips of different thicknesses or with different amounts of heat insulation or shielding. These are also proportioned or adjusted so that normal temperature rises will not cause false alarms.

Combined Fixed-Temperature and Rate-of-Rise Elements.—The expansion and bimetallic type rate-of-rise elements can be equipped with additional contacts so as to operate at given fixed temperatures irrespective of the rate of rise. Accordingly, operation is assured even though the rate of rise is insufficient to cause contact between the two elements of the rate-of-rise device.

Types of Systems.—For one type of system the thermosensitive elements are placed in parallel between the two portions of the circuit, with contacts normally open. On being actuated by fire, the contacts close, thereby operating the alarm devices. For automatic supervision over this type of circuit, a high resistance is placed at the ends of line conductors between the two sides of the circuit, thus enabling a small supervisory current to flow without actuating the fire alarm relay but which is sufficient to energize a trouble relay also in the circuit. If any break occurs, the trouble relay is de-energized, making an electrical contact and giving a trouble signal. For an ungrounded electrical source of energy, a single ground will not give either a fire alarm or trouble signal. The power source can, however, be grounded through a high resistance to give a trouble signal for a ground on either side of the circuit. For grounds on both sides of the circuit, a fire alarm is given.

In another type of circuit the thermosensitive elements are connected in series with the line conductor, and a high resistance relay is introduced to limit the normal current flow. The thermostats on being actuated open the circuit which de-energizes the relay and causes an alarm. The power source may be connected to ground through a high resistance, and relays introduced to give trouble signals for grounds at any point in the circuit. An accidental break will cause a fire alarm to be given. If the conductors of a loop are shorted on each other, neither a trouble nor a fire alarm signal will be given, and the operation of a thermosensitive element located between such points will not give a fire alarm signal. The possibility of this occurrence can, however, be made remote if the wiring is properly insulated.

Other types of circuits for automatic fire alarm systems have been devised consisting of two or more loops whereby fire alarm signals will be transmitted even if one or two lines are broken. This is effected through the trouble relays which, when actuated, automatically cause circuit adjustments to be made whereby the alarm can be received through the unbroken portions of the circuit. This adjustment can also be made manually on receipt of the trouble signal.

Local alarms consist of one or more independent units that contain all parts needed for detection and alarm. By means of some form of thermosensitive element, usually of the fixed-temperature type, a bell, whistle, or buzzer, located within the unit and operated by spring tension or from the electrical supply of the building, is actuated. The usefulness of this type of system is limited by the relatively small range within which the alarm can be received. It would be almost totally ineffective in unoccupied buildings. As applied, for instance, in two-story dwellings, a local alarm located in the basement should arouse sleeping occupants on the second floor.

Electrical Tests.—Thermosensitive elements connected with electrical circuits are generally given a breakdown voltage test of 1,000 volts, plus the operating voltage. Other tests to determine the electrical insulation afforded are also applied, depending on the nature of the device.

Relays are required to withstand operation tests involving 50,000 repetitions without appreciable deterioration. Bell

wiring is subjected to the electrical breakdown tests. Electrical insulation tests are applied to the whole system after installation.

Tests for Mechanical Damage and Vibration.—Tests are made to determine the susceptibility of parts, such as thermosensitive elements, to mechanical damage, particularly damage that renders them inoperative without giving any automatic or readily observed indication of this condition. Vibration tests are made to determine susceptibility to false alarms under the intended conditions of service.

Corrosion Tests.—Thermosensitive elements are subjected to corrosive atmospheres, salt sprays, etc., to determine how these affect reliability and sensitivity of operation.

Determining the Temperature of Operation.—The temperature of operation of fixed-temperature thermosensitive elements is determined in air, oil, or water baths, the temperature rise within or near the operating range being not more than 1° F./min. In general, the most accurate determinations can be made with the oil bath. As an indication of proper control in manufacture and to avoid unduly high or low operating temperatures, a limit of 5° F. above or below the rated operating temperature has been applied for fixed-temperature elements.

Sensitivity Tests.—The object of the sensitivity test is to determine on a comparative, if arbitrary, basis the sensitivity of response of thermosensitive elements to temperature rise. The equipment and method of conducting the test must be chosen so as to avoid: (1) variations in results caused by thermal lag of the temperature-indicating instruments, and (2) effects from radiation and air convection in the oven in which the tests are made. In tests as conducted at the Bureau, the temperature is measured with thermometers or thermocouples having known coefficients of thermal lag. Direct effects of radiation from the heating elements of the oven are largely obviated by providing screens between the thermosensitive element and heating coils. Free natural convection obtains within the oven and no recourse is made to fans or other methods of providing artificial convection. This is done on the assumption that an actual fire may not be in a location where there would be direct radiation on the thermo-

sensitive elements, or the radiation may be effectively absorbed by smoke. Since thermosensitive elements as a rule are not symmetrical on all sides from the standpoint of sensitivity to temperature response, it is believed that mounting the element on the ceiling of the oven, in which the air circulates by natural convection currents only, probably simulates average fire exposure conditions.

In conducting a test, the oven temperature is raised slowly to about 99° F., after which more current is applied, the door is closed, and test started when the temperature reaches 100° F. The rise in the oven is regulated by thermocouples, points on the thermocouple control curve and corresponding points on the thermometer curve being given in the following table. The reference thermometer is Tycos 7A539584, 750° F., lag coefficient in still air, 2 min. 15 sec. Stem 15½ inches long, 9/32 inch diameter. Bulb 3/4 inch long, 11/16 inch diameter.

Time Min.:Sec.	Reference Thermometer ° F.	No. 24 Gage Thermocouple ° F.
0:00	100	100
0:30	127	171
1:00	150	205
1:30	172	228
2:00	190	242
2:30	205	252
3:00	218	261
3:30	227	269
4:00	235	276
4:30	243	283
5:00	250	289
5:30	255	294
6:00	260	300

Above this the rate of rise is 10° F. per minute.

For testing rate-of-rise elements, the same oven is employed but the temperature rise is made as nearly linear as possible. Tests are made with different rates down to the point where no operation is obtained.

In the above tests, fixed-temperature elements are required to operate within 3½ minutes. The settings of pneumatic tube, rate-of-rise elements are required to be made so that under conditions least favorable for response

(minimum length or percentage of tubing exposed at locations most remote from diaphragms), operation will take place on rates of rise of 40° F. per minute or less, and under conditions most favorable for response (maximum length or percentage of tubing exposed in portions of circuit near diaphragms), no operation will occur with rates of rise of 4° F. per minute or less.

Tests of Systems.—Operation tests have been made of the systems, with thermosensitive elements placed on the ceilings of rooms from 140 to 1,000 sq. ft. in area. Alcohol in pans of different sizes, and wood, excelsior, and paper in piles are used as fuel for the test fires. The tests are designed to give information on the performance of the whole system and on requirements for sensitivity and spacing of thermosensitive elements.

General Results.—Very few failures have occurred in the electrical tests. In the mechanical breakage tests some weaknesses have developed, which can generally be corrected by changes in material and design. A number of the devices failed in the corrosion tests, but passed after changes had been made in material, or protective coatings had been applied to such parts as contact points and surfaces of bimetallic elements. With suitable control in manufacture, the temperature of operation of elements of the fusible solder, bimetallic, and mercurial types, will come within the required tolerance. The silica glass bulb elements had in general the widest range. Many rejections in the initial tests were due to lack of sensitivity. By changes in design to obtain fuller exposure of the heat-actuated element, in the material and dimensions, and in the operating temperature, it was possible for most devices to meet this requirement. Lowering the operating temperature increases the sensitivity, the permissible range of which is taken to be 135° to 165° F. for locations where room temperatures do not exceed 100° F. Higher operating temperatures are required where higher room temperatures prevail, but the sensitivity requirement is waived provided the device meets the requirement with the lower operating temperature.

THE FRANKLIN INSTITUTE

STATED MONTHLY MEETING, FEBRUARY 18, 1937.

The regular monthly meeting of the Institute was called to order at 8:30 o'clock by Mr. Philip C. Staples, President. It was announced that the minutes of the previous meeting had been printed in the February issue of the Journal of the Institute, and if there were no objections or corrections the minutes would be approved. Upon hearing none, the chairman declared them approved as printed.

The chairman then called upon the Secretary to read the appointments of the standing committees of the Institute for the year 1937, which are as follows:

Committee on Library.

Mr. H. Bruce Andersen
Mr. Clifford W. Bates
Mr. William G. Ellis
Mr. George S. Gardner
Mr. F. Lynwood Garrison
Mr. J. G. R. Hecksher
Mr. L. H. Hendrixson
Dr. Joseph S. Hepburn
Mr. Lionel F. Levy
Dr. Max Trumper

Committee on Meetings.

Dr. James Barnes
Dr. George S. Crampton
Dr. T. G. Delbridge
Mr. W. H. Fulweiler
Dr. A. W. Goodspeed
Mr. Charles Penrose
Mr. Coleman Sellers 3rd
Dr. W. F. G. Swann
Mr. James G. Vail
Mr. W. C. Wagner

The Board of Managers recommended the election of the following gentlemen, recipients of the Franklin medal, for Honorary membership:

Dr. Robert Andrews Millikan of Pasadena, California
Dr. Peter Joseph Wilhelm Debeye of Berlin, Germany

No objection being offered, it was so ordered.

The Secretary reported the following additions to membership since last report: Institute members—15; Museum members—32, making a total of 47.

The chairman then introduced the speaker of the evening, Dr. Robert R. Williams, Chemical Director, Bell Telephone Laboratories, Inc., of New York City, who addressed the meeting on "The Quest of Vitamin B_1." The speaker sketched briefly the history of the discovery of the vitamin with particular reference to its association with human beriberi in the Orient. After touching on the outstanding events of a twenty-year study of its isolation, attention was directed to the steps by which, under Dr. William's leadership, the chemical structure of the substance has recently been established and confirmed by synthesis. The relation of the vitamin to human diets and health in the western world was reviewed in an attempt to appraise the practical importance of recently acquired knowledge of structure and the availability of commercial supplies of the synthetic vitamin.

The subject was illustrated by lantern slides and specimens. After a spirited discussion the chairman conveyed the thanks of the meeting to the speaker.

Adjourned.

HENRY BUTLER ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, February 10, 1937.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, FEBRUARY 10, 1937.

DR. WINTHROP R. WRIGHT *in the Chair.*

The following report was presented for final action:

No. 3022: Work of Dr. Wm. F. Giauque in the Field of Low Temperatures.

This report recommended the award of the Elliott Cresson Medal to Dr. William Francis Giauque, of Berkeley, California, "In consideration of his outstanding contributions made to our scientific knowledge in the attainment of temperatures approaching within one-fourth of one degree of the absolute zero and of his systematic observance and investigation of various substances at these low temperatures."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

The library is open for consultation as follows: Mondays, Tuesdays, Fridays and Saturdays 9 A.M. until 5 P.M., Wednesdays and Thursdays, 2 until 10 o'clock P.M. 720 readers consulted the library during January.

RECENT ADDITIONS.

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LONG, ARTHUR W. The Constellations as Seen from South Africa on Any Night in the Year. Second Edition. 1923.

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Chemistry and Chemical Technology.

Beilsteins Handbuch der organischen Chemie. Erstes Ergänzungswerk. Bd. 22–25. 1936.

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Jahresbericht über die Leistungen der chemischen Technologie. Patentregister 1925–1935. 1936.

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MACDOUGALL, FRANK H. Physical Chemistry. 1936.

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WARD, A. F. H. Applied Chemistry for Engineers. 1936.

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MILLER, MAX C. Knitting Full-Fashioned Hosiery. First Edition. 1937.

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ADAM, ALASTAIR THOMAS. Wire-Drawing and the Cold Working of Steel. Second Edition. 1936.

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OBERHOFFER, PAUL. Das technische Eisen: Konstitution und Eigenschaften. Dritte verbesserte und vermehrte Auflage von W. Eilender und H. Esser. 1936.

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DORR, JOHN V. N. Cyanidation and Concentration of Gold and Silver Ores. First Edition. 1936.

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BULLOCK, E. R. Chemical Reactions of the Photographic Latent Image. Volume I, 1927. Eastman Kodak Company Monographs on the Theory of Photography No. 6.

CAMERON, JAMES R. Sound Equipment, Motion Picture Projection, Public Address Systems. 1936.

SCHWIDEFSKY, K. Einführung in die Luft- und Erdbildmessung. 1936.
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EDDINGTON, SIR ARTHUR. Relativity Theory of Protons and Electrons. 1936
FEATHER, N. Introduction to Nuclear Physics. 1936.
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BOOK REVIEWS.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS:

Report No. 573. Aerodynamic Characteristics of N.A.C.A. 23012 and 23021 Airfoils with 20-Percent-Chord External-Airfoil Flaps of N.A.C.A. 23012 Section, by Robert C. Platt and Ira H. Abbott. 20 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

The results of an investigation of the general aerodynamic characteristics of the N.A.C.A. 23012 and 23021 airfoils, each equipped with a 0.20c external-airfoil flap of N.A.C.A. 23012 section, are presented. The tests were made in the N.A.C.A. 7- by 10-foot and variable-density wind tunnels and covered a range of Reynolds Numbers that included values corresponding to those for landing conditions of a wide range of airplanes. Besides a determination of the variation of lift and drag characteristics with position of the flap relative to the main airfoil, complete aerodynamic characteristics of the airfoil-flap combination with a flap hinge axis selected to give small hinge moments were measured in the two tunnels. Some measurements of air loads on the flap itself in the presence of the wing were made in the 7- by 10-foot wind tunnel.

From the data obtained, the external-airfoil flap in combination with an airfoil appears to be one of the most generally satisfactory high-lift devices investigated to date. The combination tested offers a relatively high value of maximum lift coefficient with low profile drag in the high-lift range. At low-lift coefficients it gives very nearly as low values of profile drag as a good plain airfoil of comparable

thickness. Structural and stability problems associated with the large negative pitching moments occurring at high-lift coefficients may be slightly greater than in the case of ordinary and split flaps.

Report No. 574. Pressure Distribution Over an Airfoil Section with a Flap and Tab, by Carl J. Wenzinger. 11 pages, diagrams, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

Pressure-distribution tests of a Clark Y airfoil with a flap and an inset tab were made in the N.A.C.A. 7- by 10-foot wind tunnel. The pressures were measured on both the upper and lower surfaces at one chord section. Calculations were made of the normal-force and pitching-moment coefficients of the airfoil section with flap and tab, the normal-force and hinge-moment coefficients of the flap section with tab, and the normal-force and hinge-moment coefficients of the tab section alone. In addition, comparisons were made of the theoretical and experimental values for an airfoil with a multiply hinged flap section.

It was found that peak values of the increments of resultant pressures due to flap or to tab deflection occurred at the flap and tab hinges, respectively. Also, the variations of increments of airfoil section normal-force and pitching-moment coefficients and of flap normal-force and hinge-moment coefficients, due to flap deflection with a given tab setting, were practically independent of the tab deflection. In addition, the variation of increments of tab normal-force and hinge-moment coefficients with tab deflection for a given flap setting was practically independent of flap deflection. Comparisons of the theoretical with the experimental forces and moments for the airfoil section with flap and tab show that the theory agrees fairly well with experiment for small flap deflections with the tab neutral, but that the theory indicates much greater effects than are actually obtained when the flap and tab are simultaneously deflected.

Report No. 578. Flight Measurements of the Dynamic Longitudinal Stability of Several Airplanes and a Correlation of the Measurements with Pilots' Observations of Handling Characteristics, by Hartley A. Soule. 6 pages, diagrams, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

The dynamic longitudinal stability characteristics of eight airplanes as defined by the period and damping of the longitudinal oscillations were measured in flight to determine the degree of stability that may be expected in conventional airplanes. An attempt was made to correlate the measured stability with pilots' opinions of the general handling characteristics of the airplanes in order to obtain an indication of the most desirable degree of dynamic stability. The results of the measurements show that the period of oscillation increases with speed. At low speeds a range of periods from 11 to 23 seconds was recorded for the different airplanes. At high speeds the periods ranged from 23 to 64 seconds. The damping showed no definite trend with speed. A general tendency for airplanes that were stable with power off to become unstable with power on was noted. The maximum damping recorded was sufficient to reduce the amplitude of oscillation by one-half in 9 seconds, or approximately one-fourth cycle. The opinions of two pilots concerning the handling characteristics of the airplanes apparently were not influenced by the stability characteristics as defined by the period and damping of the longitudinal oscillations.

Report No. 567. Propulsion of a Flapping and Oscillating Airfoil, by I. E. Garrick. 9 pages, tables, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

Formulas are given for the propelling or drag force experienced in a uniform air stream by an airfoil or an airfoil-aileron combination, oscillating in any of three degrees of freedom: vertical flapping, torsional oscillations about a fixed axis parallel to the span, and angular oscillations of the aileron about a hinge.

Report No. 572. Determination of the Characteristics of Tapered Wings, by Raymond F. Anderson. 20 pages, tables, diagrams, 23 × 29 cms. Washington, Superintendent of Documents, 1936. Price ten cents.

Tables and charts for use in determining the characteristics of tapered wings are presented. Theoretical factors are given from which the following characteristics of tapered wings may be found: The span lift distribution, the induced-angle-of-attack distribution, the lift-curve slope, the angle of zero lift, the induced drag, the aerodynamic-center position, and the pitching moment about the aerodynamic center.

The wings considered cover the complete range of taper ratios and a range of aspect ratios from 2 to 20. The factors given include the effects of sweepback and twist and apply to wings having a straight taper plan form with rounded tips and an elliptical plan form. The general formulas of the usual wing theory are also given from which the characteristics of a wing of any form may be calculated when the section characteristics are known from experiment.

In addition to the tables and charts, test results are given for nine tapered wings, including wings with sweepback and twist. The test results verify the values computed by the methods presented in the first part of the report. A final section is given outlining a method for estimating the lift coefficient at which a tapered wing begins to stall. This method, which should be useful for estimating the maximum lift coefficient of tapered wings, is applied to one of the wings tested.

Report No. 580. Heat Transfer to Fuel Sprays Injected into Heated Gases, by Robert F. Selden and Robert C. Spencer. 17 pages, tables, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1937. Price ten cents.

A study has been made of the influence of several variables on the pressure decrease accompanying injection of a relatively cool liquid into a heated compressed gas. Indirectly, this pressure decrease and the time rate of change of it are indicative of the total heat transferred as well as of the rate of heat transfer, between the gas and the injected liquid. Air, nitrogen, and carbon dioxide were used as ambient gases; Diesel fuel and benzene were the injected liquids. The gas densities and gas-fuel ratios covered approximately the range used in compression-ignition engines. The gas temperatures ranged from 150° C. to 350° C.

Several general conclusions may be drawn from the experimental results: Vaporization begins immediately after the start of injection; the initial rate of heat transfer is a direct function of the initial temperature difference between the gas and the fuel; and the heat transfer is less efficient the greater the injected fuel quantity, even though the total heat transferred is greater.

PHYSICAL CHEMISTRY, by Frank H. MacDougall, M.A., Ph.D. 721 pages, tables, diagrams, 15 × 22 cms. New York, The Macmillan Company, 1936. Price $4.00.

Here is a text that is intended to be quite flexible in its application. It may be used by those who desire a rigid treatment of the subject and who have all of the prerequisites and qualifications for such treatment, those who desire a general concept of the subject and who have partial prerequisites, and it even possibly may be used by those who desire to improve their cultural development and whose background is of more of a general educational nature. With all people, technically inclined, there is agreement that a knowledge of the subject is useful especially in view of very evident possibilities for new developments.

The author begins this text earlier than the usual, including in it an introductory treatment of the atomic theory and leading to the first and through the second laws of thermodynamics and subjects associated with them. A few of the important equations are derived here which provide a basis for what follows. Then the subjects treated include solutions, thermochemistry, equilibrium, applications of the phase rule, chemical kinetics, electrical conductance, electrolysis, photochemistry, and colloids. On the subject of equilibria involving ions, the Debye equation for the activity coefficient of a strong electrolyte is derived from the Boltzmann theorem and Poisson's equation. The present state of knowledge of the reader of course is the determining factor as to how far the details of the discussion may be followed through.

The style of presentation is a practical one. In controversial questions the author leaves room for opinions to be formed even though they may not be in agreement with his. This is an important feature particularly in view of uncertainties in many cases developed by modern thought and research.

The book is an up-to-date text, thorough and clear, and represents basic knowledge of the subject.

R. H. OPPERMANN.

RELATIVITY THEORY OF PROTONS AND ELECTRONS, by Sir Arthur Eddington, M.A., D.Sc. 336 pages, 18.5 × 27 cms. New York, The Macmillan Company. Cambridge, England, University Press, 1936. Price $5.50.

The author in the Preface states, "In this book I have endeavored to give a connected account of a series of investigations in the borderline between relativity theory and quantum theory. It begins where my earlier book, The Mathematical Theory of Relativity, leaves off—at the point where in our survey of nature we encounter the phenomenon of atomicity. To our gross senses matter seems continuous and it has been treated as continuous in the usual theory of relativity. Experiment has however taught us that it is composed of multitudes of units, and the theory is here extended to throw light on the existence and properties of these units.

"The central problem is to ascertain the conditions which fix the amount of mass and electric charge carried by protons and electrons."

The book is divided into two parts—Wave Tensor Calculus, and Physical Applications. In the former there are ten chapters beginning with the subject of tensors and matrices and proceeding through the subjects of the sixteenfold frame, the resolution of matrices, space vectors, the simple wave equation, reality con-

ditions, strain vectors and phase space, the differential wave equation, the hydrogen atom, and double wave vectors.

The second part treats on the Riemann-Christoffel tensor, the mass ratio of the proton and electron, standing waves, the cosmical problem, electric charge and the exclusion principle. The separation of the two parts is only a rough separation. Physical interpretations are considered very early but with the introduction of double wave tensors the relation of the mathematics to the physics changes considerably. Instead of starting with the mathematical result and interpreting it as far as possible physically, the physical problem is started and formulated mathematically. The auxiliary mathematical development still continues but it is guided by the character of the physical problem for which its aid is required.

This book, by a famous author, should find much use by physicists who in turn will find much of interest in the results given.

R. H. OPPERMANN.

AN INTRODUCTION TO NUCLEAR PHYSICS, by N. Feather, Ph.D. 213 pages, tables, diagrams, 14.5 × 22.5 cms. Cambridge, University Press, 1936. Price 10 shillings 6d.

This subject is brought forward in the scientific world at an increasing rate. While to many it may seem a far cry from a field of pure research to the field of practical applications we have only to point to one of the multitude of scientific developments in use every day for confirmation of results of pure research. But now experiments are being performed in pure research that need explanations and various explanations need verification in experiments. Out of all this there finally comes another "scientific wonder." The subject of nuclear physics has untold possibilities.

The book at hand is both an introduction and a summary. The extension of the history of the concept of atom-of-matter which received numerical expression merely as a result of calculations is the story of modern physics in one of its major aspects. This is sketched in the introductory chapters of this book. It is shown how the notion of spatial extent is particularized and the idea of structure is introduced, under the necessity of interpretation for more detailed experiments. Description is given of the types of measurement made in experiments of nuclear physics and inquiry is made as to how far the interpretation of such experiments may be carried in terms of the concept of macroscopic physics—the ideas of the engineer and the astronomer—or to what extent an entirely new point of view may be necessary.

The introductory experiments are divided into experiments concerning the properties of radioactive material or of matter subjected to the action of radiations from radioactive substances, investigations of matter in general by the method of mass spectroscopy, investigations of matter by the method of optical spectroscopy, and experiments involving the bombardment of matter by artificially accelerated particles.

Part II of the book, on the stable nuclei, III on the unstable nuclei, and IV transformations produced by fast-moving particles and by radiation, are the main concern of the book, after the broad outlines of structural pattern have been accepted, and it is here necessary to particularize still further and assign structure to the atomic nucleus.

The book gives clearly the main ideas necessary for an understanding of current research on this subject.

R. H. OPPERMANN.

SENIOR SCIENCE SOCIALIZED FOR THE HIGH SCHOOL, by George L. Bush, Theodore W. Ptacek and John Kovats, Jr. 835 pages, illustrations, 16 × 24 cms. New York, The American Book Company, 1937. Price $2.20.

Here is a book that is chuck full of interesting facts presented in an interesting way. It is an outgrowth of an unusual course in mimeographed form given in the Cleveland high schools and treats on general science in a popular way.

There are ten different parts on as many subjects. The subjects are those which are felt or seen every day and the treatment is designed to satisfy natural curiosity about them in a manner not too difficult to comprehend. For instance, the first subject is water, the life blood of the world. On this, the authors explain how dependent human existence is on this substance—as a carrier of food in the body, its purity and means for purification, mineral waters, a cleansing agent and the operation of soap in this connection, the pump, power from water, ice and its manufacture, water as a gas and its use in engines, and the chemical elements. There does not seem to be any particular plan for the sequence of subjects under the main general topic but the authors cleverly lead from one to another with apparently no interference or gaps. After a convenient group of sub-topics is treated upon there are listed suggestions for general class discussions and another listing of questions that naturally would crop up in the reader's mind. The latter are entitled "for individual assignment and research" and suggested references are given.

Other topics of the book are fire, its wonders and dangers; fuels, the comfort and convenience makers; weather and air, our constant companions; foods and medicine; textiles; building materials; home equipment; transportation; safety.

From this it can be seen that the book is neither a chemistry nor a physics text, just a plain everyday explanation of the physical and chemical nature of things about us. The authors spare nothing in making the subject clear in popular, simple language. The book is profusely illustrated and contains a subject index which adds to its value as a reference work.

While the book may be intended for use in high schools, it presents a challenge to most anyone glancing through it. Its up-to-date information and broad coverage will provide material that is sure to catch interest.

R. H. OPPERMANN.

ELECTRICITY, by W. L. Bragg, M.A., Sc.D. 272 pages, plates, 15 × 22.5 cms. New York, The Macmillan Company, 1936. Price $4.00.

The author of this book claims that the average person has difficulty in understanding how things electrical operate because of a lack of an "electrical sense." He states, "The instincts and common sense which we acquire by handling objects make it comparatively easy for us to understand heat and light and sound, and the way in which machines work, but we seem to have no electrical sense although electrical devices of all kinds play so important part in our lives." The purpose, therefore, of the book is to present the fundamental ideas of electricity in a simple manner so as to facilitate the understanding. How well this is accomplished can be seen by glancing through the work.

The first three chapters on the nature of electricity, how it travels, and magnetism leading into the operation of meters, dynamos and motors is a well done introduction. Not only analogies of various kinds serve to make the treatment interesting but descriptions of manifestations of electrical phenomena in nature furnish much that the curious mind should eagerly devour. Following these, the chapters on electrical supply, explaining power systems and alternating currents, telegraphs and telephones and how they operate, and oscillating electrical circuits including radio and vacuum tubes, give a colorful and interesting picture.

The book is well illustrated with drawings and photographs. It is written in a popular style that will undoubtedly add to the general knowledge of the layman reader and provide that which is necessary to assist in grasping the natural laws, the patient study of which has led to such remarkable developments.

R. H. OPPERMANN.

MECHANICS, MOLECULAR PHYSICS, HEAT AND SOUND, by Robert Andrews Millikan, Duane Roller and Earnest Charles Watson. 498 pages, tables, illustrations. 16 × 24 cms. Boston, Ginn and Company, 1937. Price $4.00.

This is a book that, along with its treatment of the various subjects, goes further than the usual text. It has a definite object in covering the method and scope of the topics. Its broad aim is to develop a realization that the essential strength of physics lies in its continual resort to experiment and that it is only through the constant interplay of experiment and theory that the science has obtained its enormous successes. Another aim of the book is to develop a method of thorough, exact thinking.

On opening the book one is confronted with an illustration of one of the three most famous copper engravings of the great Albrecht Dürer (1471–1528) entitled "Melancholia." The notation accompanying this is so well done in its explanations directed toward the meanings shown that it is truly an inspiration. Nor is the inspiration allowed to diminish from the beginning to the very end of the text. Ever so often at the proper place there is included some of the historical and humanistic background of the subject. Much of this appears in the form of chapter introductions and plates.

The study of the subject is taken up in conjunction with laboratory work. The chapter headings are appropriate to the title of the book and the treatment emphasizes fundamentals. Experiments are described for each chapter at its end which is followed by what is termed a "Question Summary." This consists of a number of questions that can be answered orally, the object being to form a valuable summary of the important topics covered and at the same time to materially increase mastery of the subject. Following this, there is a list of problems accompanied by their answers. Here it is explained, the ability to solve problems is not only a dependable test of one's mastery of the science but is an index of the growth of one's powers to meet and solve original situations and to use the subject as a tool in further thinking.

The structure of the entire text is so composed that the book is remarkable for its ability to catch and hold interest. Everything that should be told is told, and told in an impressive way. Likewise unnecessary and unrelated material is avoided. Great emphasis is placed on the source literature of the field and on the value of collateral reading. References are noted throughout the treatment and a bibliography is appended.

For the student who has had trigonometry and the equivalent of a good secondary course in physics this book can be recommended. It is an outstanding modern text.

R. H. OPPERMANN.

THE MECHANICAL TESTING OF METALS AND ALLOYS. THE THEORY AND PRACTICE OF STANDARDIZED MECHANICAL TESTING, by P. Field Foster, B.Sc. 285 pages, illustrations, 14 × 22 cms. New York, Pitman Publishing Corporation, 1936. Price $3.75.

This book gives the theory underlying present-day developments in the testing of metals and their alloys together with descriptions of modern testing equipment and its use. The plan of the book intermingles these subjects in such a way that a logical trend is shown. It starts out with a treatment on the elementary theory of elasticity which is followed by the structure of metals. Machines for tension and bending, torsion, hardness, impact, and repeated stresses are described as well as universal testing machines, extensometers and recorders, and the testing of wire and sheet metal. The last chapter of the book deals with some test phenomena and results such as the influence of the shape of the test piece on the stress-strain diagram, influence of mild heat treatment and periods of rest, compression, and creep tests. There is given a table of properties of metals and alloys and a bibliography.

The book is well illustrated with drawings and photographs and the descriptions are unusually clear. It should be very useful to those whose interests bring them in contact with the subject.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

The History of the Discovery of Photography, by Georges Pontonniee, translated by Edward Epstean. 272 pages, 16 × 24 cms. New York, Tennant and Ward, 1936. Price $8.00.

The Theory of Metals, based on an Essay Awarded the Adams Prize in the University of Cambridge, 1931–1932, by A. H. Wilson. 272 pages, illustrations, 14.5 × 22 cms. Cambridge, University Press, 1936. Price $5.00.

A Laboratory Guide to the Study of Qualitative Analysis, by E. H. S. Bailey and Hamilton P. Cady, 10th edition. 322 pages, diagrams, 15 × 22 cms. Philadelphia, P. Blakiston's Son & Co., Inc. Price $2.00.

Analytic Geometry and Calculus, by Bolling H. Crenshaw and Cincinnatus D. Killebrew, second edition. 222 pages, diagrams, 16 × 24 cms. Philadelphia, P. Blakiston's Son & Co., Inc. Price $2.75.

Ions in Solution, by R. W. Gurney. 203 pages, illustrations, 14 × 22.5 cms. Cambridge, University Press, 1936. Price $3.00.

United States Bureau of Mines. Statistical Appendix to Minerals Yearbook, 1935. 442 pages, 15 × 23.5 cms. Washington, Government Printing Office, 1936. Price $1.25.

Canada Department of Mines. Investigations in Ore Dressing and Metallurgy, January to June 1935. 237 pages, tables, 17 × 25 cms. Ottawa, King's Printer, 1936.

The Mechanics of Instantaneous Acetate Recording, by Sam. W. Hawver, unpaged, 16 × 22 cms. Los Angeles, Cellutone Record Manufacturing Co. Price fifty cents.

Public Works Administration. The First Three Years, 44 pages, illustrations, 17 × 24 cms. Washington, Government Printing Office, 1936.

Association of Consulting Chemists and Chemical Engineers. Directory of Association Members, November 1, 1936. Third Edition. 59 pages, 22 × 28 cms. New York, Association, 1937.

Canada Dominion Bureau of Statistics. Report on the Leather Footwear Industry in Canada, 1935. 22 pages, tables, 22 × 28 cms. Ottawa, King's Printer, 1937. Price twenty-five cents.

National Advisory Committee for Aeronautics. Technical Notes No. 589, Theoretical Span Loading and Moments of Tapered Wings Produced by Aileron Deflection, by H. A. Pearson. 30 pages, figures, tables. No. 590, Hydrodynamic Tests in the N.A.C.A. Tank of a Model of the Hull of the Short Calcutta Flying Boat, by Kenneth E. Ward. 11 pages, diagrams. No. 591, Full-Scale Span Load Distribution on a Tapered Wing with Split Flaps of Various Spans, by John F. Parsons and Abe Silverstein. 10 pages, figures. 3 pamphlets, 20 × 26 cms. Washington, Committee, 1937.

CURRENT TOPICS.

Clocks Showing Mean Time and Sidereal Time Simultaneously.—Readers may be interested to know that the Dr. Comrie who hit upon the extraordinarily precise ratio expressed in the wheel numbering of a gear train, was, until last year, the Editor of the *Nautical Almanac*. He has made a special study of Calculating Machines, and has established a Scientific Computing Service at Clifton House, St. Pancras, London, N. W.

With our *present* definitions of the motion of the mean sun, which is measured from the mean equinox, containing a T^2 term, the ratio of sidereal to mean time is not constant, so that it is impossible for a gear train, however accurate, to represent it for ever.

H–J.

Recovery of CO_2 from Flue Gas.—Prof. B. F. DODGE and C. L. COMSTOCK of Yale University presented a paper recently before the symposium on Absorption and Extraction held at Columbia University under the auspices of the American Chemical Society on this subject from which better predictions may be made. Carbon dioxide is usually extracted from other gases by means of bringing the gas mixtures into contact with a liquid which will absorb it. To do this a tower is so constructed that the liquid trickles around broken solids in the opposite direction to the gas flow. The liquid is usually a solution of potash or soda ash and this has the property of absorbing carbon dioxide at one temperature and releasing it at another. The paper is an endeavor to give information so that the tower may be constructed on a more scientific basis. Various factors affecting the efficiency of absorption were investigated with a small tower only 3 inches in diameter packed with small glass rings and it was possible to translate the laboratory results to large scale towers. It was found that the size of the tower could be reduced by increasing the flow of liquid, the maximum absorption rate will be reached at 55° C. and higher temperatures result in reduced absorption rate. Carbonate solutions are not well suited, and rate of absorption is not affected by rate of gas flow.

R. H. O.

Scattered Construction Operations Connected by Radio Telephone.—R. B. LORD. (*Engineering News Record*, Vol. 117, No.

25.) At Eastport, Maine, during the preliminary construction operations for the Passamaquoddy Bay tidal power development, a communication system was found to be necessary that was foolproof and economical to install and operate. Radio telephone met all requirements. Stations were located in the administration building at operations headquarters, at Carlow Island, at Treat Island and aboard the floating plant from which borings were taken. The total installed cost of the four sets was $1186 or about $296 for each complete unit in operating condition, and $928 for the operating cost. This is far less than either wireless telegraphy or direct wire telephone was estimated.

R. H. O.

German Open-Jet Wind Tunnel.—(*Engineering*, Vol. CXLII, No. 3701.) An interesting apparatus for the testing of aeroplane models is the wind tunnel erected for the Deutsche Versuchsanstalt für Luftfahrt, at Berlin-Adlershof. It consists of an open jet of elliptical section, the horizontal axis measuring 23 ft. and the vertical axis 16 ft. 5 in.; the section can, however, be enlarged to 26 ft. 3 in. by 19 ft. 8 in. if required. Models with a wing span up to 14 ft. 9 in. can thus be tested as well as fuselages complete with engine, radiators, etc. The closed circuit through which the air is circulated is rectangular in plan with an overall length of 159 ft. and is constructed of reinforced concrete, partly circular and partly elliptical in cross section. Just before the air reaches the discharge nozzle it passes through a multi-tubular grid which serves to render the flow rectilinear. The nozzle opens into the test room and after passing over the model which is suspended from a balance in this room, passes into a mouthpiece and returns to the closed circuit. The air is circulated by an eight-bladed air screw 27 ft. 11 in. in diameter directly coupled to a 2700 h.p. electric motor which runs at either 125 or 250 r.p.m. and is enclosed in a streamline casing. The maximum speed of the air at the outlet nozzle is 155 miles per hour. This can be varied by adjusting the pitch of the propeller blades which are of hollow cast Silumine. The adjustment can be made while the propeller is running. The air in circulation is kept cool and pure by withdrawing some of it through slots and discharging it to the atmosphere automatically. The air velocity over the whole section of the jet does not vary by more than 1.5 per cent. under the most unfavorable conditions.

R. H. O.

New Alloy Extends Range of Electric Heat Application.—H. E. KOCH. (*Electrical World*, Vol. 107, No. 3.) For a long time there

has been a continuous search on the part of electric furnace builders for a heating element which could be run at temperatures higher than those possible with nickel chrome materials. Recently the A. O. Smith Corporation became interested in this problem and Dr. S. L. HOYT and Mr. R. ARCHER with others discovered an alloy of iron, chromium and aluminum which was a somewhat radical departure from previous productions. It proved quickly to have outstanding characteristics when used at elevated temperatures. As soon as reasonable quantities of wire were available test furnaces were built on a semi-commercial scale. Two such furnaces are still in operation and on one of these a Telechron hour counter indicated 18,700 hours of operation at all temperature ranging from 2000 to 2300 deg. and including several overheating cycles where the temperature was as high as 2500° F. The new alloy is known as "Alloy 10." Of all the properties of this new alloy the specific resistance of 1000 ohms per cir. mil ft. is of special interest. This is approximately 50 per cent. greater than nickel chromium grades and permits with equal ampere ratings an increase of 50 per cent. in the power liberated by the element. An important characteristic which gives "Alloy 10" high resistance to destructive oxidation is an aluminum oxide which forms initially on the surface of the wire when heated to operating temperature. This oxide is practically impervious to further attack, either by oxidizing or reducing gases, and makes it possible to use the alloy under varying conditions of furnace chamber atmospheres. The use of this alloy should be of interest in such applications as the heat treating of metal products and ceramic ware, the treatment of high speed steels, and for firing of pottery and china ware.

R. H. O.

Butane Used as Refrigerant in Home Air Conditioning Installation.—A. S. JAMES. (*National Petroleum News*, Vol. XXIX, No. 2.) Normal butane, now in demand as a liquefied petroleum gas because of its heating qualities has proved itself desirable in just the opposite role—that of refrigerant in an air-conditioning unit. Practical demonstration of this is to be found in the Tulsa home of Paul M. Raigorodsky, where an experimental unit built more than a year ago has developed into an economical and efficient system so successfully that an application has been made for a patent. The installation's design is similar to the conventional ammonia absorption system used in the manufacture of ice, except that butane and octane are used instead of ammonia and water for the circulating mediums. With butane it is possible to obtain temperatures in the evaporator as low as 35 to 40 deg. when oper-

ating the evaporator at atmospheric pressure. A hydrocarbon having the characteristics of octane is used for absorbent. This liquid has a relatively low boiling point, which enables the still to be operated at a temperature around 250° F. This low temperature does not cause the absorbent to disintegrate and coke the pipes. These two hydrocarbons also give a high degree of separation when using only single flash vaporization, thus eliminating the necessity of an elaborate fractionating apparatus and reducing the fuel consumption to a minimum. The whole unit with the exception of auxiliary equipment is located on a concrete foundation about 6 ft. by 12 ft. The only moving parts are small pumps. Air-conditioning is accomplished by continuously chilling and circulating the air in the rooms. A steam boiler in the system, for furnishing heat to separate the butane and the octane, is used, during months when heat is required, as a hot water heater. The water is pumped through a fin type air cooler which then becomes an air heater and the heated air is circulated around the house.

R. H. O.

Hot Well Water Cooled for Use in City Distribution System.—(*Engineering News Record*, Vol. 118, No. 4.) Six years ago the city of Riverside, Calif., added to its water supply system an artesian well which produced 2000 g.p.m. The water in all respects was up to standard requirements except that its temperature was 110 deg. F. Part of the flow was put into the city water supply along with cool water from other wells but the result was to raise the average temperature to an objectionable degree, so the hot well water had to be substituted by cold water from another source. Recently it was decided to employ an evaporation process to cool the hot water sufficiently to permit using it in the city system. A cooling system was built, designed on the principle of evaporating water in contact with tubes containing the hot water. A concrete basin 25 × 175 ft. in plan with walls 12 in. high was built. Extending the length of this basin and some 6 ft. above it are 42 thin galvanized iron tubes 2 in. in diameter arranged in seven vertical tiers of six tubes each. These cooling tubes are served at one end from a 12 in. header bringing the hot water from the well via a booster pump. At the other end the tubes discharge into a 12 in. header leading to the city mains. The circulating water is taken from the hot well and goes first to the concrete basin in which float valves maintain a depth of about 4 in. From two sumps in the concrete basin, pumps circulate the cooling water so as to keep the surface of the cooling tubes covered with water. The transfer of heat from the tubes to the circulating water plus evaporation cools the well water

in the tubes. There are 2 pumps each with a 1200 g.p.m. capacity delivering to V-troughs above the top of each tier of 2 in. tubes. From this source water from the circulating system trickles down over the tubes. Below the tiers is a screen which causes the cooling water to fall in a spray to the basin below thereby cooling it.

R. H. O.

Artificial Snow for Indoor Winter Sports.—C. F. HOLSKE. (*Refrigerating Engineering*, Vol. 33, No. 2.) For years, many of the engineering profession have devoted their time to the creation and maintenance of artificial weather conditions in enclosed spaces, but in general this control has not extended into the realm of artificial blizzards. The first really man made snow storm was at Madison Square Garden in New York recently for a sports show and skiing. Erection of the ski slide at a late hour required, between the hours of 5 A.M. and 2 P.M., the trucking of 214 tons of ice, the conversion of it into snow, and the slinging of it into position on the slide and the arena floor. Ice in 300 pound blocks was hoisted to platforms and fed to crushers by a gang of men. After crushing into snow it was spread by snow machines. A number of these machines were installed on platforms near the top of the slide and the snow distributed through hoses to the desired place. This snow was apparently a satisfactory substitute for the natural article, as the expert skiers from all over the world who engaged in the exhibition managed to indulge themselves in ski jumping, slalom racing and down hill running without any serious difficulty. During the exhibition, the Garden was maintained at a temperature approximately equal to that of outdoor air temperature. As this was quite warm some difficulty was anticipated but the snow did not melt very rapidly. During the night following each day it was necessary to add more snow to insure good footing for the exhibitors. The average quantity of ice required for this operation was approximately 75 tons per day.

R. H. O.

Hydrogen for Fuel.—(*The Technology Review*, Vol. 39, No. 3.) According to Hector Bywater, naval correspondent of the *London Daily Telegraph*, the adoption of a new type of engine for submarines by the British navy is only a question of time. Several years ago Rudolf A. Erren, a German engineer, perfected a hydrogen engine for utilizing off peak power from hydroelectric stations. Excess electric current is fed to electrolyzers which separate water into its component elements at pressures of 3000 to 4000 pounds per square inch. The gases, stored in steel cylinders, are then burned as

needed but not necessarily together, for hydrogen can be used with air or mixed with some liquid fuel. When, however the two gases in their pure form are used, an expanding medium, such as steam from the exhaust must be introduced into the cylinder, for hydrogen and oxygen in the proportion of two to one occupy more space than the water vapor that is the result of the explosion. Operating thusly, the engine exhibits a unique characteristic. It is entirely independent of the atmosphere around it and if the steam coming from the cylinders is condensed, does not exhaust into the air. Such qualities immediately suggest its use where air is precious. It may be possible that the single engine submarine can be driven, while on the surface, by a Diesel engine which can be quickly converted, when submerging, into a hydrogen-oxygen engine. Additional auxiliaries of course are necessary such as electric ignition etc. The gases are stored separately in cylinders which take up about half the space and less than half the weight of the displaced storage batteries. When the craft submerges, the gases are led to the engine at, or slightly above, atmospheric pressure, burned, and the products of combustion (water vapor) condensed and sent back to the electrolyzers.

R. H. O.

Garbage Used as Fuel in 1250 KW. Electric Plant.—(*Power Plant Engineering*, Vol. XLI. No. 2.) The new Providence, R. I., incinerator plant with waste heat boilers to produce electric power for the city's sewage plant is the result of a two years' investigation. The plant contains a 5 cell incinerator having a capacity of 160 tons of refuse per 24 hr. and an overload capacity of 200 tons per 24 hr. Trucks discharge the refuse into a large storage bin from which the incinerator hoppers are charged periodically by means of an electric crane. Air for combustion under the grates is supplied by a turbine driven forced draft fan. Two boilers are installed, one operating and one spare. These have a steam capacity of 700 hp. and are designed to generate steam at 200 lb. pressure and 100 deg. superheat. The gases from the incinerator have a temperature of 1450 deg. and may be delivered to either of the two boilers. Steam from these boilers is delivered to two 1250 kw. turbine generators. The plant is located adjacent to the sewage disposal plant which requires a load of about 750 kw. Approximately 1500 ft. away is the sewage pumping station which is now operated by steam engine driven pumps about 40 yr. old. Plans call for the motorization of the station and when this work is completed, sufficient power will be available from the incinerator plant for operating the station.

R. H. O.

Gland Serum Produced at 40 Below.—(*Electrical World*, Vol. 107 No. 5.) Frigidaire engineers recently were called upon to provide a temperature of 40 deg. below zero continuously for the manufacture of a serum in a California sanitarium. Two standard compressors operating in conjunction with a condenser of a special design and a heat interchanger were installed. The process involves distillation and condensation of extract of steer supernal glands at this low temperature as well as refrigerated storage for glands awaiting processing.

R. H. O.

A New Inorganic Cement and Adhesive.—D. S. HUBBELL (*Industrial and Engineering Chemistry*, Vol. 29, No. 2). Magnesium oxychloride cements were first described by Sorel, a French chemist in 1876. Since then, these cements have been the subject of much research because they possess a unique combination of properties that offers many possibilities in the building arts. They have many advantageous properties and have had some limitations. The latter includes their solubility, the excessive volume changes sometimes encountered, and efflorescence and incompatibility with Portland cement compositions or other materials that contain lime. Recent research has disclosed that the addition of copper powder to magnesium oxychloride cements in the form of extremely fine dendritic particles results in an improvement that is directly proportional to the amount added, up to 10 or 11 per cent. While these changes may be considered as an improvement in the original composition, the effect of the addition is more accurately described as the creation of a new element whose physical properties embrace all of the good but none of the bad characteristics of magnesium oxychloride cement. The cement so produced is highly insoluble in water and free from excessive expansion even when placed in contact with materials that contain lime or when magnesium oxides are used that would otherwise have caused disastrous increases in volume; it is almost entirely free from efflorescence, and has a strength when dry nearly twice and when wet nearly three times that of the original cement. The development provides the building arts with a much needed inorganic adhesive. The plastic nature of the compositions permits easy application.

R. H. O.

Sweet-Potato Starch.—H. G. KNIGHT (*Manufacturers Record*, Vol. CVI, No. 2). One of the newest industries in the South is the production of sweet-potato starch. Chemists have found that sweet potatoes not only contain enough starch to make it profitable

to process them, but that the starch is of such high quality that it can be used in cotton mills, adhesive factories, commercial laundries, and indirectly in the manufacture of postage stamps. Sweet-potato starch is not new, for Japan has been making it for many years, but as little effort is made to remove the natural yellow color, the sale of Japanese starch is restricted. In this country, as a result of continued research, chemists succeeded in solving the color problem and the starch that is being made in a new factory at Laurel, Miss., not only has a beautiful white color but is of an unusually high quality. This factory, built from an allotment of the Federal Emergency Relief Administration, has a capacity of 200,000 bushels of sweet potatoes and 2,000,000 pounds of starch per 100 day season. It has been deeded to the Mississippi Agricultural Experiment Station. The cost of starch manufacturing is such that it is reasonable to assume that Southern industry as well as Southern agriculture will be greatly benefited. The United States consumes more than 1,000,000,000 pounds of starch a year. There is imported approximately 250,000,000 pounds a year which represents the productive capacity of some 300,000 acres. Sweet-potato starch can supplement the present cereal starch and similar factories to the one at Laurel, Miss., can be built at a reasonable cost. It will require 150 factories of similar size to make as much starch as is now imported.

R. H. O.

Mercury Tubes for Purifying Air.—DR. WILLIAM F. WELLS of the Harvard School of Public Health told recently, at a six-day symposium of the school, of experiments with germs of diseases such as the common cold. He suggested that, because from actual tests on twenty-five Harvard students subjected to sneezing which resulted in exposing countless nose and throat germs, the air in public buildings should be purified similarly to the purification of drinking water. Dr. Wells demonstrated with a machine known as an air centrifuge, how fine particles in the air are circulated, contaminating a large area, and he explained how an ultra-violet light may be used in purification of the air. A fifty-watt mercury lamp can purify 10,000 cubic feet of air per minute.

R. H. O.